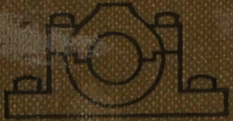
MACHINE DRAWING PROBLEMS



BERG AND ELLESON

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MACHINE DRAWING PROBLEMS

A TEXT AND PROBLEM BOOK INVOLVING A STUDY OF FUNDAMENTAL ELEMENTS OF MACHINE CONSTRUCTION AND PRACTICE IN THE CONVENTIONAL REPRESENTATION OF MACHINE PARTS

BY

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PREFACE

THE aim of this book is to provide text matter and a course of problems which embody some of the fundamental elements of machine construction and afford practice in the conventional representation of machine parts. It is designed as an advanced course for students who have had previous instruction in mechanical drawing and is intended for school use. The problems have been so chosen as to acquaint the student with the most common principles and materials used in machine construction, for the assembling of parts, transmission of power, control of motion, etc., and to offer training in the making of complete and accurate drawings of machine details and small machines.

Each problem is presented in the form of a specification sheet and a lay-out sheet. The specification sheet furnishes direction and instruction for the solution of the problem, and information and references relative to the nature and the use of the object to be drawn. The lay-out sheet suggests the arrangement of views, conventional methods of representation, etc. From this material, together with information or data previously gained or used, the student is to make the completed drawing.

The problems are arranged in four main groups, namely: Machine Fastenings, Appliances for the Transmission of Power, Devices Controlling Motion, and Small Machines. In addition to these, there is also a selection of miscellaneous extra problems for supplementary work. The groups should be followed in the order given and the work in one group should be covered as thoroly as the time will permit before starting the next group.

The authors are indebted to various manufacturers for contributing blue prints and information which were used in preparing the course. They are indebted to the Brown & Sharpe Manufacturing Co. and to the Fellows Gear Shaper Co. for assistance in preparing the gear manuscript and especially to Frank E. Eberhardt, of the Newark Gear Cutting Machine Co., and, at the time, president of the American Gear Manufacturers Association, for his careful reading and criticism of the manuscript on spur gears.

As a reference book, or for preparing class lectures, on modern drafting-room practice, *Mechanical Drawing,* by Franklin D. Jones, published by the Industrial Press, N. Y., is highly recommended.

THE AUTHORS.

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SMALL MACHINES.............................. 114
Bench Shear; Rotary Oil Pump; Gasoline Feed Pump.

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Disc Crank; Curved Arm Pulley; Punch Press Fly Wheel; Bearing and Cap; Air Compressor; One-Fourth H. P. Motor; Wire Rope Drum; Positive Action Cam; Wedge Socket for Steel Wire Rope; Worm and Worm Wheel.

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OUTLINE OF PROBLEMS BY GROUPS

GROUP 1

MACHINE FASTENINGS

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APPLIANCES FOR TRANSMISSION OF POWER

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OUTLINE OF PROBLEMS BY GROUPS—Continued

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27. Gas Engine Connecting Rod...............112

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Title Page

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GENERAL DIRECTIONS

This course of problems in machine drawing is intended for students who have had previous work in mechanical drawing equivalent to that covered by the book *Mechanical Drawing Problems*, by Berg and Kronquist, published by The Manual Arts Press, Peoria, Ill. Each problem is selected to teach certain things which thru careful study and solution the student is to learn and apply. The student is not only to make the drawing involved but is to study carefully the information and references given so as to be able to answer questions concerning the use of the object drawn, the proportion of parts, methods of representing, etc. The material for each problem should be read and studied before beginning to draw. Knowing just what is wanted and how to do it is half the job done.

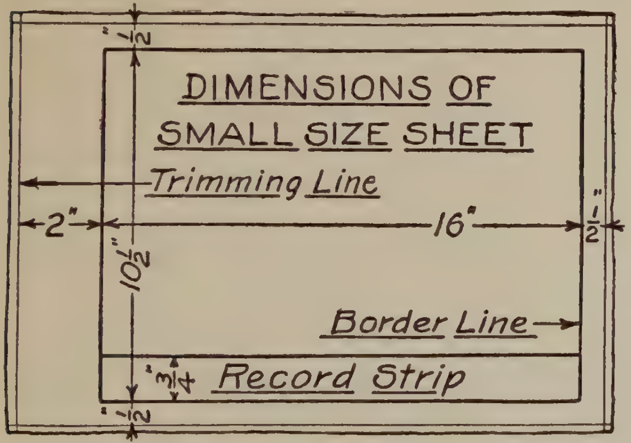
Size of Paper.—The drawings are made in two sizes which are known as the Small Size Sheet and the Large Size Sheet. "Royal" size paper, 19 inches by 24 inches, is used for the large size and cut into two sheets, 12 inches by 19 inches, for the small size. The dimensions for drawing the border line, trimming line, etc., are given on page 7. Unless otherwise mentioned in the specification for a problem, the small size sheet is to be used.

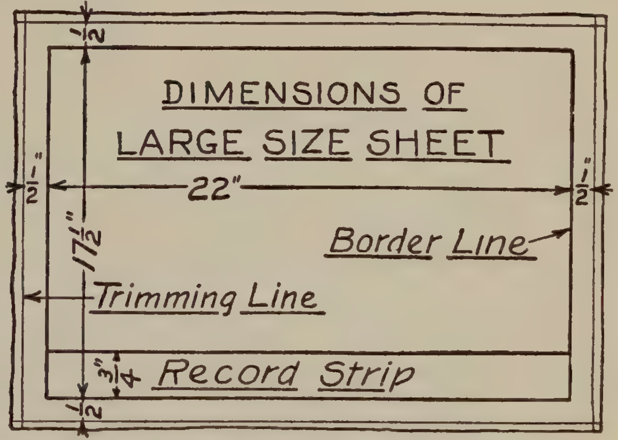
Record Strip.—A record strip, containing the name of the machine or machine part, the scale, the date, etc., should be included in every drawing. Two forms of record strips are shown on page 7.

Lettering.—The Gothic style of letter is to be used in all lettering on the drawings. Suggestive sizes and kinds are given on page 9. All lettering should be done neatly and so that the words are legible and easily read.

Bill of Material.—On page 9 is given a form for a Parts List or Bill of Material. The list should include the number of each part required, the name of each part, the kind of material the part is to be made of, the reference, or identification number of each part, and the pattern number of parts that are to be cast. Sometimes a further space is required for remarks relative to changes, methods of manufacture and miscellaneous information. A bill of material is generally given on an assembly drawing or on a detail drawing in which all the parts of a machine or unit of a machine are drawn on one sheet. The reference number of a part should be placed in a circle near the drawing of the views representing it and must correspond to the one used in the bill of material. When a bill of material is not given on a sheet which has drawings of several parts on it, each part should have a sub-title giving the name of the part and information concerning the number required, material, etc., placed near the views representing the part.

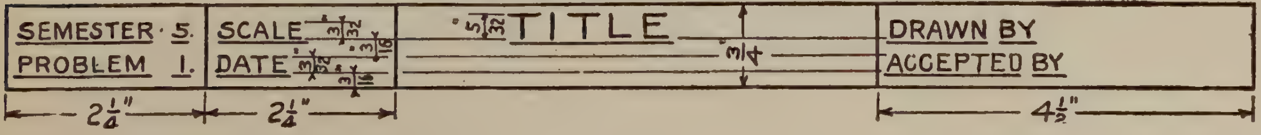
Dimensions.—The dimensions are the most important part of a working drawing. An accurate drawing neatly executed may not be worth the paper it is drawn on if it does not include all the dimensions needed in the shop or if some of the sizes given are incorrect. While it is usually desirable to make a drawing quite accurate so as to show clearly to which parts or surfaces the given dimensions apply, a poorly executed drawing which is correctly dimensioned is much superior to a drawing which is neatly executed and pleasing to the eye but has mistakes or omissions in dimensions.

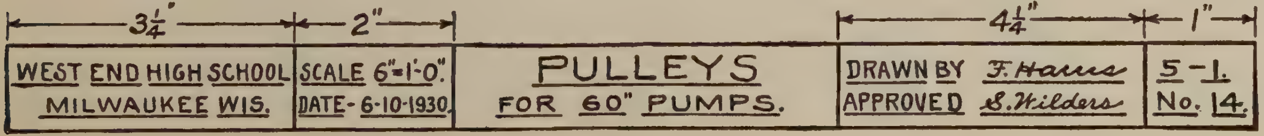




NOTE-Dimensions given on layout sheet for locating views are enclosed in a circle They should not be placed on the finished drawing

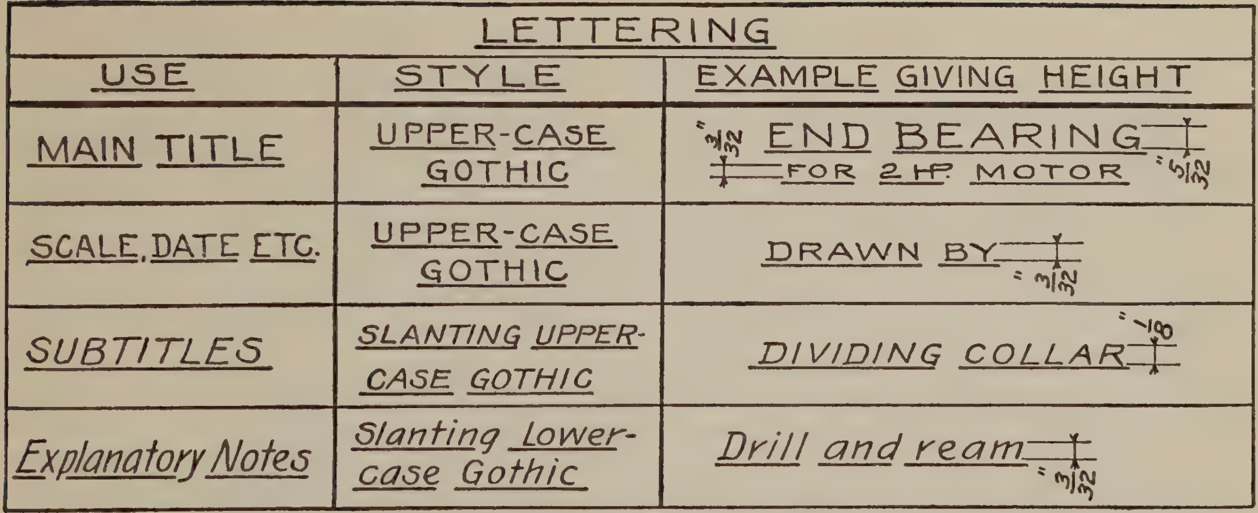
SUGGESTIONS FOR RECORD STRIP





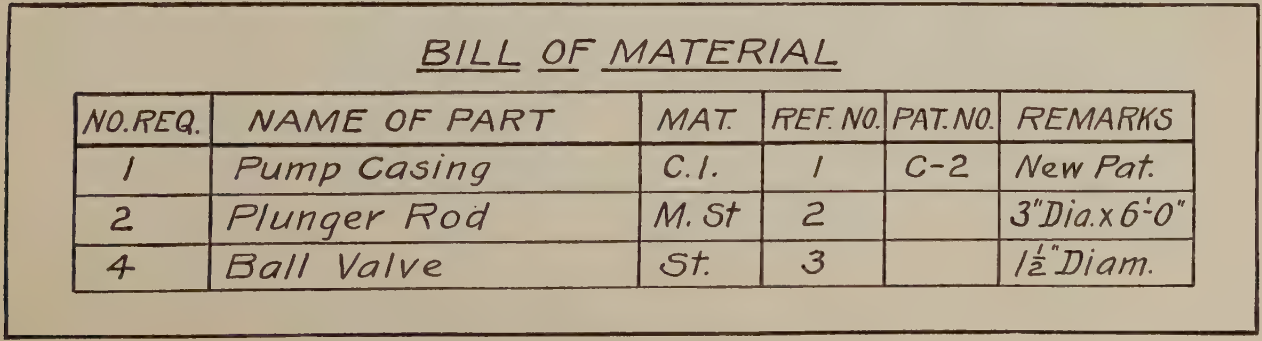
DECIMAL EQUIVALENTS OF PARTS OF AN INCH

Com. Frac.	Dec.	Com. Frac.	Dec.	Com. Frac.	Dec.	Com. Frac.	Dec.	Com. Frac.	Dec.	Com. Frac.	Dec.
1/64	.01563	13/64	.20313	21/64	.32813	33/64	.51563	45/64	.70313	57/64	.89063
1/32	.03125	7/32	.21875	11/32	.34375	17/32	.53125	23/32	.71875	29/32	.90625
3/64	.04688	15/64	.23438	23/64	.35938	35/64	.54688	47/64	.73438	59/64	.92188
1/16	.0625	¼	.25	⅜	.375	9/16	.5625	¾	.75	15/16	.9375
5/64	.07813	17/64	.26563	25/64	.39063	37/64	.57813	49/64	.76563	61/64	.95313
3/32	.09375	9/32	.28125	13/32	.40625	19/32	.59375	25/32	.78125	31/32	.96875
7/64	.10938	19/64	.29688	27/64	.42188	39/64	.60938	51/64	.79688	63/64	.98438
⅛	.125	5/16	.3125	7/16	.4375	⅝	.625	13/16	.8125	1	1.00000
9/64	.14063			29/64	.45313	41/64	.64063	53/64	.82813		
5/32	.15625			15/32	.46875	21/32	.65625	27/32	.84375		
11/64	.17188			31/64	.48438	43/64	.67188	55/64	.85938		
3/16	.1875			½	.5	11/16	.6875	⅞	.875		



LETTERING

USE	STYLE	EXAMPLE GIVING HEIGHT
MAIN TITLE	UPPER-CASE GOTHIC	3/32" END BEARING FOR 2 H.P. MOTOR 5/32"
SCALE, DATE ETC.	UPPER-CASE GOTHIC	DRAWN BY = 3/32
SUBTITLES	*SLANTING UPPER-CASE GOTHIC*	*DIVIDING COLLAR* = 1/8
Explanatory Notes	*Slanting Lower-case Gothic*	*Drill and ream* = 3/32



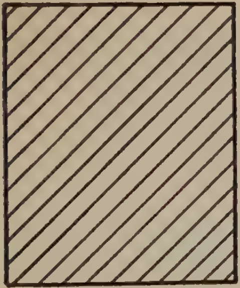
BILL OF MATERIAL

NO. REQ.	*NAME OF PART*	*MAT.*	*REF. NO.*	*PAT. NO.*	*REMARKS*
1	*Pump Casing*	*C. I.*	*1*	*C-2*	*New Pat.*
2	*Plunger Rod*	*M. St*	*2*		*3" Dia. x 6'-0"*
4	*Ball Valve*	*St.*	*3*		*1½" Diam.*

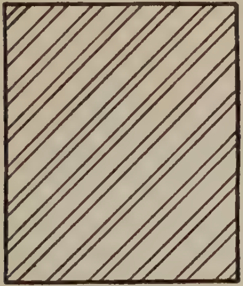
CROSS-SECTIONS AND CROSS-HATCHING

When an object is of such a shape or construction that a drawing of it involves many broken lines to show hidden parts, it is advantageous to show a view with part of the object cut away or removed, thus allowing the hidden parts to stand out in full view. This is called "cross sectioning" or simply "sectioning" and the view is said to be "in section" or partly in section. To indicate that a view has been drawn in section, light parallel lines which are evenly spaced are drawn across the surface or surfaces of the parts that are cut. This is known as "cross-hatching." In assembly drawings that are shown in section, it is necessary to make some distinction between the different pieces. This is usually done by using different kinds of cross-hatching lines for different materials and by inclining the lines of adjacent parts in different directions.

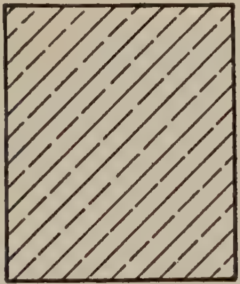
On the following page is shown a simple system of cross-hatching for different materials, which is quite commonly used in machine drawing. Other systems are in use as there is no universal standard. Some systems are very elaborate and the different kinds of steel, such as machine steel, cast steel, steel casting, alloy steels, etc., are represented by different kinds of lines. A simple system, however, is more desirable as all that is necessary is to indicate in a general way the kind of material so as to make it easier to read the drawing and understand the relation of parts, one to the other. The special kinds of steel or other material can best be indicated with written notes.



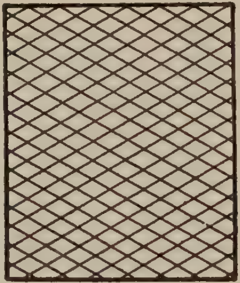
CAST IRON.



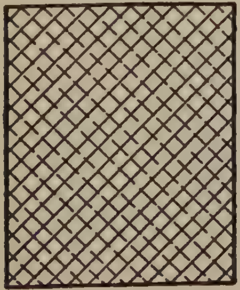
STEEL.



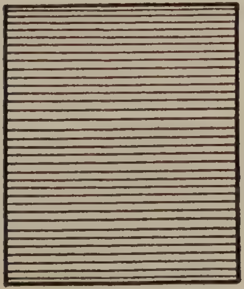
COPPER, BRASS
OR
BRONZE.



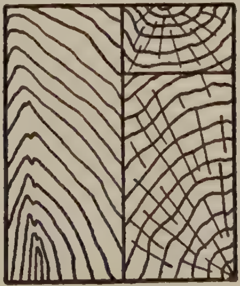
BABBITT
OR
WHITE METAL.



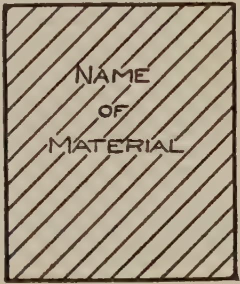
ALUMINUM.



FIBER
OR
HARD RUBBER.



WOOD.



OTHER
MATERIALS.

SCREW THREADS

A screw is a cylindrical bar having a helical projection called a thread. Hence the curve of a screw thread is a helix. A helix is the path of a point traced on the surface of a revolving cylinder as the point moves at a uniform rate of speed along a line which is parallel with the axis of the cylinder, and at some regular prescribed proportion of travel in this direction to each revolution of the cylinder. The pitch of the helix is the distance between any two points in the path of the curve measured parallel with the axis of the cylinder. Fig. 1 illustrates the method of constructing a helix and Fig. 2 shows the method of drawing the actual helical curves in a screw thread.

Details of Screw Threads.—Fig. 3 represents a drawing of a screw with the names of the parts. Screws may have either a right-hand or a left-hand thread, and may have either single, double, or other multiple threads. A screw with a right-hand thread must be turned in a clockwise direction to enter a nut or threaded hole. A screw with a left-hand thread must be turned counterclockwise when entering a threaded hole. See Figs. 4 and 5. A single thread screw has a single helical projection; a double thread screw has two adjacent helical projections. See Figs. 6 and 7. Multiple threads are used when a quick advance of the screw or nut is desired. The pitch of a screw is the distance from center to center of two adjacent threads. The lead of a screw is the distance the screw will advance thru a nut if turned around one complete revolution. See Fig. 8 and 9. Single threaded screws are designated by the number of threads per inch rather than by the pitch of the thread. A screw is designated by its outside diameter, the number of threads per inch or the pitch of the thread, and the shape or form of the thread. Screw threads are understood to be single and right-hand unless otherwise specified.

SCREW THREADS

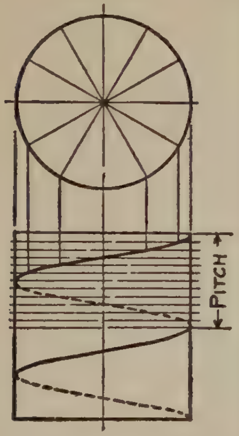


FIG. 1

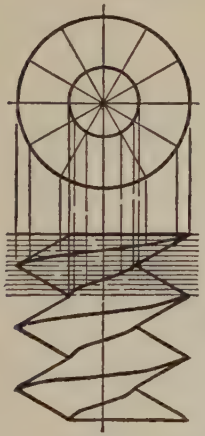


FIG. 2

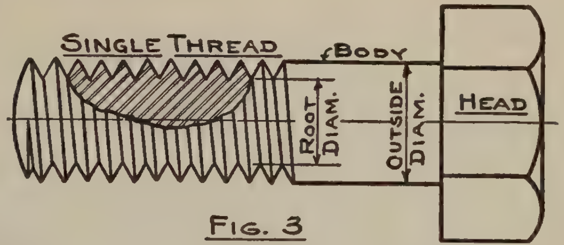
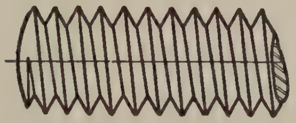
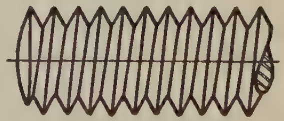


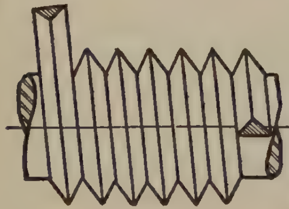
FIG. 3



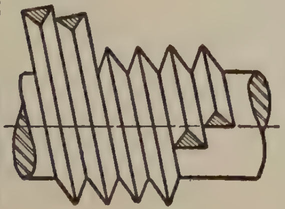
RIGHT HAND THREAD
FIG. 4



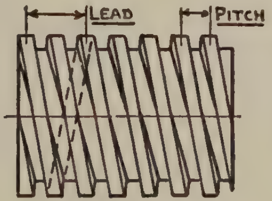
LEFT HAND THREAD
FIG. 5



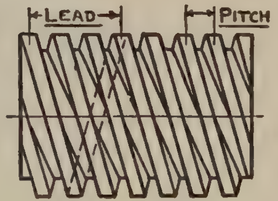
SINGLE THREAD
FIG. 6



DOUBLE THREAD
FIG. 7



DOUBLE THREAD
FIG. 8



TRIPLE THREAD
FIG. 9

SCREW-THREAD FORMS

As the screw and nut are used on almost every mechanical device, various forms of threads have been developed. Some of these have become so generally used for certain purposes that the shapes and proportions have become standardized. Altho threads are seldom drawn as they actually appear, the student should become familiar with the common styles.

Sharp V-Thread.—The use of this form of thread is confined chiefly to small screws. Because it is practically impossible to make cutting tools which will form the sharp *V* edges without wearing out rapidly, the American manufacturers of taps and dies are making a united effort to retire the *V* thread in favor of the U. S. Standard.

United States Standard Thread (U. S. S.).—Due to the flattening of the tops and bottoms of the V's, this form of thread is much stronger and more easily cut than the sharp *V* thread. It is the most common form of screw thread in the United States and is used generally for bolts and other fastenings in machine construction.

Square Thread.—The square thread is the most efficient form to transmit motion or power and is used in jack-screws, vises, lathe chucks, etc. Altho there is no recognized standard of proportions, those adopted by the Wm. Sellers Co. are used quite generally.

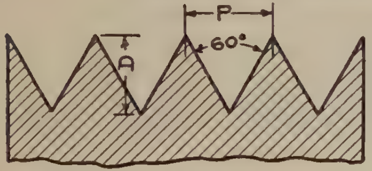
Acme Thread.—The acme thread is used to transmit motion and is the standard form for lead screws of lathes and similar service. It is generally used with a split nut which permits compensation for wear and allows its being engaged or disengaged quickly. It is stronger than the square thread and easier to cut.

Buttress Thread.—The buttress thread is designed for the transmission of power in one direction only. It is used on breech blocks of guns and occasionally in vises.

British Standard Whitworth Thread.—The Whitworth thread is the standard used in England for bolts, screws, etc. It is more difficult to form than the U. S. S.

SCREW THREAD FORMS

SHARP V-THREAD

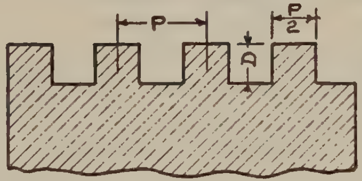


P = PITCH OR

$P = \frac{1}{\text{No. THDS PER INCH}}$

D = DEPTH = .866P

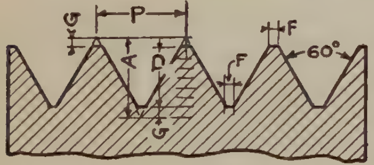
SELLERS SQUARE THREAD



D = .4375P

NUMBER OF TH'DS PER INCH IS USUALLY $\frac{1}{2}$ OF U.S. OR V-THDS.

U.S. STANDARD (OR SELLERS) THREAD



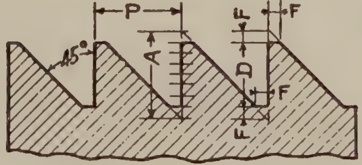
A = .866P

D = .65P OR .75A

F = .125P

G = .108P OR $\frac{A}{8}$

BUTTRESS THREAD

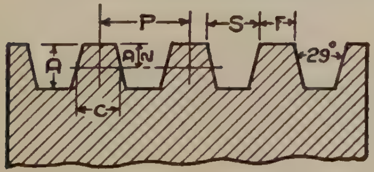


A = P

D = .75P

F = .125P OR $\frac{A}{8}$

ACME STANDARD THREAD



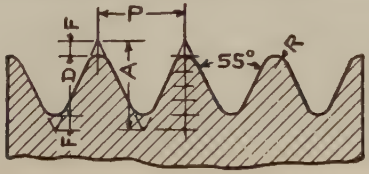
D = .5P + .01"

F = .37P

S = .63P

C = .5P

BRITISH WITHWORTH STANDARD THREAD



A = .96P

D = .64P

F = .16P OR $\frac{A}{6}$

R = .137P

STANDARD SCREW-THREAD PITCHES

Standards designating the number of threads per inch for a given diameter have been designed with an attempt to equalize the stresses in the thread and in the bolt or screw. The most common standards in the United States are those which apply to the U. S. Standard form of thread and are known as the United States Standard Screw Thread (U. S. S.); the Society of Automobile Engineers Screw Standard (S. A. E. St'd.); and the American Society of Mechanical Engineers Standard for Machine Screws (A. S. M. E. St'd.).

The U. S. S. threads, form and pitch, are for general use in engineering work and machine construction on bolts, screws, and other threaded components where quick and easy assembly of the parts is desired. The number of threads for certain diameters is given on page 21.

The S. A. E. Standard pitch was adopted for general use on screws and bolts in automotive work. The threads are finer for a given diameter than in the U. S. S. and allow for the accurate adjustments demanded in automobile construction. The number of threads and corresponding diameters are given in the table of S. A. E. screws on page 24.

The A. S. M. E. Standard was adopted for use on a special type of small screws known as machine screws. It includes several pitches for a certain diameter. See page 27.

The U. S. Congress, by its act of July, 1918, authorized the National Screw Thread Commission. The purpose of this Commission was to establish screw-thread standards for use of manufacturers and various branches of the Federal Government. The Commission has adopted and recommends two thread systems which are called the "National Coarse Thread Series" and the "National Fine Thread Series." The coarse thread series contains certain sizes known previously as the U. S. S. threads and also certain sizes known as the A. S. M. E. machine-screw threads. The fine thread series contains certain sizes known previously as the S. A. E. threads and also certain sizes known as the A. S. M. E. machine-screw sizes. The "National" form or profile of thread, which is the same as the U. S. S., is used in both series.

DRAWING OF SCREW THREADS

In the drawing of a screw, the actual projection of the thread requires too much time, and hence conventional representations which are more simple to draw are generally used. For U. S. S. threads of very coarse pitch, and when screws are shown in section, the representations of Fig. 13 may be used. For small diameters the representations of Figs. 10, 11, and 12 are most commonly used. If a threaded hole does not extend thru a piece, the bottom of the hole should be drawn, as shown, to the angle of a drill point, which is about 120 degrees.

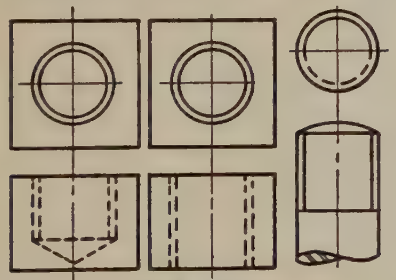


FIG. 10

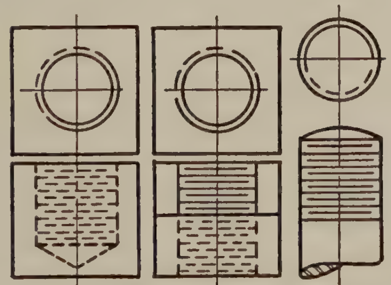


FIG. 11

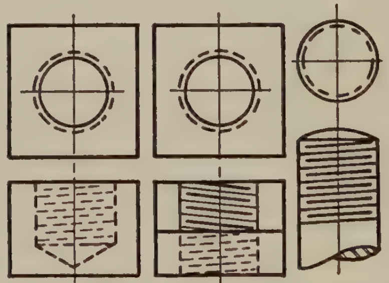


FIG. 12

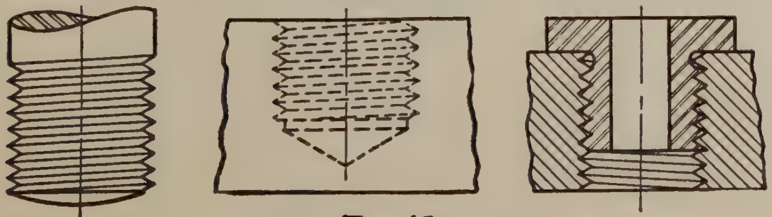


FIG. 13

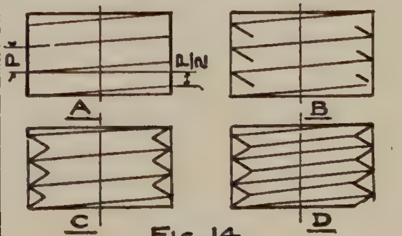


FIG. 14

STANDARD BOLTS AND SCREWS

There are many types of screw fastenings some of which have been standardized and are regularly kept in stock by manufacturers who make a specialty of such parts. Those most commonly employed in machine construction are known as bolts, cap-screws, machine screws, studs, and set-screws. Each of these general classes includes different forms or types which are distinguished by variations of the shape of the head, etc. The sizes of bolts and screws kept in stock can best be obtained from manufacturers or dealers catalogs. The use of such catalogs is highly recommended.

Bolts.—A bolt is a round bar of steel, one end of which has an enlargement or head, while the other end has a thread cut on it to carry a nut. Bolts are used to fasten two or more machine parts together and are well adapted for this purpose as they allow the parts to be easily disconnected. The most common forms of bolts are known as machine bolts, carriage bolts, and coupling bolts.

U. S. Standard Machine Bolts.—Machine bolts are made with square or hexagonal heads which may be rough or finished. The body of the bolt is rough and for this reason the hole thru which it passes is sometimes made larger than the diameter of the bolt so as to make assembling easy. The standard lengths of machine bolts as given in the manufacturers catalogs vary by ½-inch increments on bolts from 1 to 8 inches long; over 8 inches, the lengths vary by 1-inch increments. The length of the threaded part is generally from three to four times the height of the nut. The threads are U. S. S. form and U. S. S. pitch. See page 22.

Coupling Bolts.—A coupling bolt is a machine bolt that is finished so that it will fit accurately into a reamed hole of the same diameter as the nominal diameter of the bolt. It is carried in stock with hexagon heads and nuts only and is intended for use in shaft couplings, etc., in which the bolts prevent lateral movement of the parts clamped. The heads and nuts are either finished or semi-finished, the latter being faced true with the body of the bolt. The threads are U. S. S. form and U. S. S. pitch. See page 25.

Carriage Bolts.—The carriage bolt, another form of thru bolt, is used chiefly in connection with wood construction. It has a square section underneath the head to prevent the bolt from turning in the hole when tightening the nut. The threads are U. S. S. form and U. S. S. pitch. See page 21.

Screws.—Screws are used to fasten together two machine parts when it is impossible or inconvenient to use a thru bolt and nut. They are screwed directly into one of the parts to be fastened, which is threaded and hence acts as a nut. Cap-screws and machine screws hold the pieces together by the pressure exerted by the head of the screw as it is turned, while set-screws prevent relative motion between two parts by the friction of the point which presses against one of the pieces.

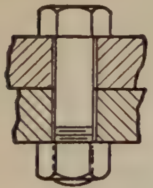
Cap-screws.—Cap-screws are made with many styles of heads, the square and hexagon being the most commonly used. Manufacturers differ somewhat as to the size of the heads, but the thread used is U. S. Standard form and pitch. In all cap-screws of one inch and less in diameter and four inches long and under, threads are usually cut three-fourths of the length; longer than four inches, threads are cut half of the length. For standard length of cap-screws see dealers' or manufacturers' catalogs. See page 23.

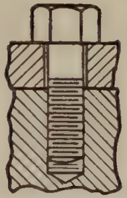
Machine Screws.—Machine screws are a form of small cap-screw that are designated by gauge numbers instead of by the diameter of the body in inches and are provided with a slotted head for a screw driver. The American Society of Mechanical Engineers standard dimensions for machine screws are used quite generally. The form of thread is U. S. S. The pitch is A. S. M. E. standard or special. A machine screw of a given diameter, as No. 10, may be purchased with 30 threads per inch which is standard, or with 32 threads per inch which is special. For standard lengths see dealers' catalogs. See pages 26 and 27.

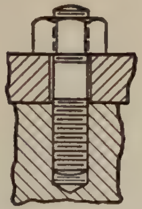
Set-screws.—Set-screws are generally used for holding pulleys, collars, etc., on shafts. They are made with square heads or headless. The threads are U. S. Standard form and pitch. The headless set-screws, also known as safety set-screws, are provided with a slot for a screw driver or with an angular hole in the body of the screw which necessitates a special wrench for tightening. There are many forms of points, the cup point and oval point being the most common. For standard lengths see dealers' catalogs. See page 25.

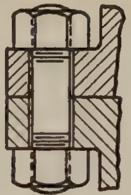
Studs.—A stud is a headless screw used in place of a cap-screw on machine parts that must be removed frequently. Studs are usually employed to secure the heads of cylinders in engines and pumps. The wear and crumbling of the threads in a weak material such as cast iron are avoided as when the stud is screwed into place it becomes a part of the casting and the wear then comes on the nut and stud, both of which are made of steel. See page 21.

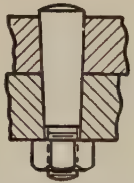
S. A. E. Screws and Nuts.—In order to fulfill the requirements of strength, space limits, and accurate adjustments demanded in automobile construction, the Society of Automobile Engineers has adopted a special type of screw known as the S. A. E. Standard Screw and Nut. The heads and nuts are hexagonal and are somewhat smaller than those on the U. S. Standard Machine bolts. The threads are U. S. S. in form but of a special pitch known as the S. A. E. Standard. The heads are slotted for a screw driver and the nuts are slotted or castellated so they may be locked to the screw by means of cotter pins which pass thru a hole drilled in the threaded end of the screw. They may be used as bolts or as cap-screws. For standard lengths see catalogs. See page 24.

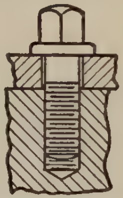

Hex. Mach. Bolt

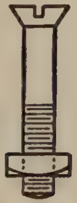

Cap Screw

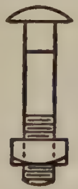

Stud

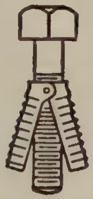

Stud Bolt

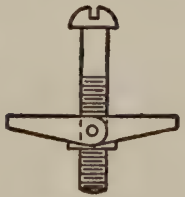

Taper Bolt

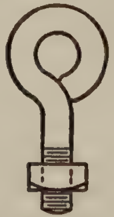

Collar Head Scr.

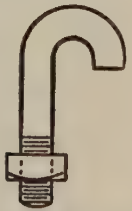

Stove Bolt


Carriage Bolt


Expansion Bolt

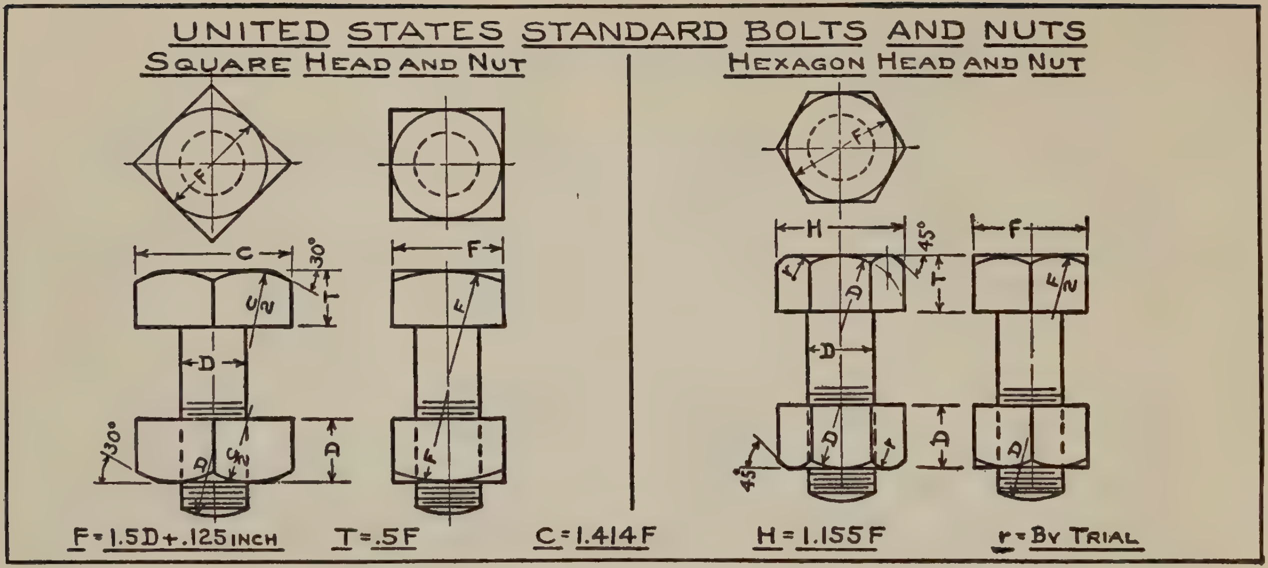

Toggle Bolt


Eye Bolt

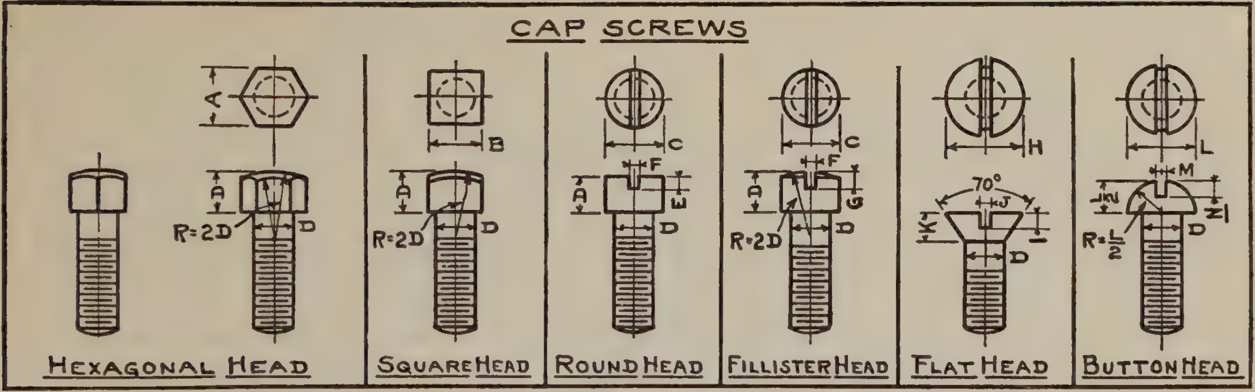

Hook Bolt

UNITED STATES STANDARD THREADS

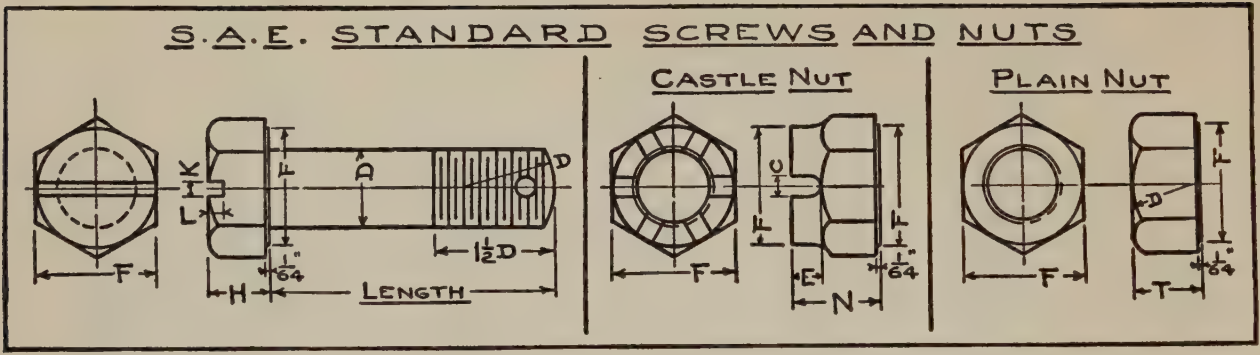
Diameter	¼	5/16	⅜	7/16	½	9/16	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝
Threads per inch....	20	18	16	14	13	12	11	10	9	8	7	7	6	6	5½
Diameter of tap drill.	13/64	¼	5/16	23/64	27/64	15/32	17/32	41/64	¾	55/64	31/32	1 3/32	1 7/32	1 11/32	1 27/64
Diameter	1¾	1⅞	2	2¼	2½	2¾	3	3¼	3½	3¾	4	4¼	4½	4¾	5
Threads per inch....	5	5	4½	4½	4	4	3½	3½	3¼	3	3	2⅞	2¾	2⅝	2½
Diameter of tap drill.	1 17/32	1 21/32	1 49/64	2 1/64	2 15/64	2 31/64	2 11/16	2 15/16	3 11/64	3⅜	3⅝	3 27/32	4 3/32	4 5/16	4 9/16



D=Diameter of bolt.........	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4
N=Threads per inch........	20	18	16	14	13	12	11	10	9	8	7	7	6	6	5 1/2	5
F=Across flats.............	1/2	19/32	11/16	25/32	7/8	31/32	1 1/16	1 1/4	1 7/16	1 5/8	1 13/16	2	2 3/16	2 3/8	2 9/16	2 3/4
C=Square across corners....	23/32	27/32	31/32	1 7/64	1 1/4	1 3/8	1 1/2	1 49/64	2 1/32	2 19/64	2 9/16	2 53/64	3 3/32	3 23/64	3 5/8	3 57/64
H=Hexagon across corners..	37/64	11/16	51/64	29/32	1 1/64	1 1/8	1 15/64	1 29/64	1 43/64	1 7/8	2 3/32	2 5/16	2 17/32	2 3/4	2 31/32	3 3/16
T=Thickness of head.......	1/4	19/64	11/32	25/64	7/16	31/64	17/32	5/8	23/32	13/16	29/32	1	1 3/32	1 3/16	1 9/32	1 3/8

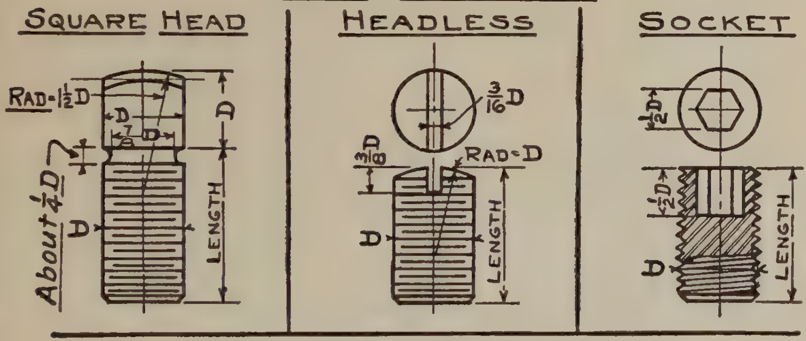


D=DIA.	THREADS PER INCH	TAP DRILL	A	B	C	E	F	G	H	I	J	K	L	M	N
1/8	40	5/64			3/16	1/16	1/32	5/64	1/4	3/64	3/64	3/32	7/32	1/32	1/16
3/16	24	9/64			1/4	1/16	1/32	3/32	3/8	1/16	1/16	9/64	5/16	3/64	3/32
1/4	20	13/64	7/16	3/8	3/8	1/16	1/16	3/32	15/32	5/64	5/64	5/32	7/16	1/16	1/8
5/16	18	1/4	1/2	7/16	7/16	5/64	5/64	1/8	5/8	3/32	3/32	7/32	9/16	3/32	5/32
3/8	16	5/16	9/16	1/2	9/16	3/32	3/32	9/64	3/4	7/64	7/64	17/64	5/8	7/64	3/16
7/16	14	23/64	5/8	9/16	5/8	7/64	7/64	11/64	13/16	1/8	7/64	17/64	3/4	7/64	7/32
1/2	13	27/64	3/4	5/8	3/4	1/8	7/64	3/16	7/8	5/32	1/8	17/64	13/16	7/64	1/4
9/16	12	15/32	13/16	11/16	13/16	9/64	1/8	7/32	1	11/64	1/8	5/16	15/16	7/64	9/32
5/8	11	17/32	7/8	3/4	7/8	5/32	1/8	15/64	1 1/8	3/16	1/8	23/64	1	1/8	5/16
3/4	10	41/64	1	7/8	1	3/16	1/8	9/32	1 3/8	7/32	1/8	7/16	1 1/4	1/8	3/8
7/8	9	49/64	1 1/8	1 1/8	1 1/8	7/32	1/8	5/16							
1	8	7/8	1 1/4	1 1/4	1 1/4	1/4	5/32	3/8							
1 1/8	7	63/64	1 3/8	1 3/8											
1 1/4	7	1 7/64	1 1/2	1 1/2											

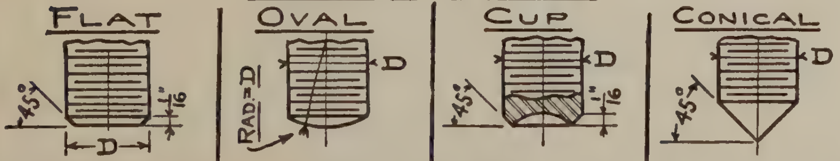


D=Diameter of bolt........	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
No. of threads per inch......	28	24	24	20	20	18	18	16	16	14	14	12	12	12	12
F=Across flats.............	7/16	1/2	9/16	5/8	3/4	7/8	15/16	1	1 1/16	1 1/4	1 7/16	1 5/8	1 13/16	2	2 3/16
H=Thickness of head	3/16	15/64	9/32	21/64	3/8	27/64	15/32	33/64	9/16	21/32	3/4	27/32	15/16	1 1/32	1 1/8
N=Thickness of nut	9/32	21/64	13/32	29/64	9/16	39/64	23/32	49/64	13/16	29/32	1	1 5/32	1 1/4	1 13/32	1 1/2
T=Thickness of plain nut...	7/32	17/64	21/64	3/8	7/16	31/64	35/64	19/32	21/32	49/64	7/8	63/64	1 3/32	1 13/64	1 5/16
C=Width of nut slot.......	5/64	5/64	1/8	1/8	1/8	5/32	5/32	5/32	5/32	5/32	5/32	7/32	7/32	1/4	1/4
E=Depth of nut slot........	3/32	3/32	1/8	1/8	3/16	3/16	1/4	1/4	1/4	1/4	1/4	5/16	5/16	3/8	3/8
K=Width of head slot.....	1/16	1/16	3/32	3/32	3/32	3/32	3/32	3/32	3/32	3/32	3/32	5/32	5/32	3/16	3/16
L=Depth of head slot......	3/32	7/64	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	7/32	7/32	1/4	1/4
Diameter of tap drill........	7/32	17/64	21/64	3/8	7/16	1/2	35/64	39/64	43/64	25/32	29/32	1 1/64	1 9/64	1 17/64	1 25/64

SET SCREWS


SQUARE HEAD
HEADLESS
SOCKET

FORMS OF POINTS

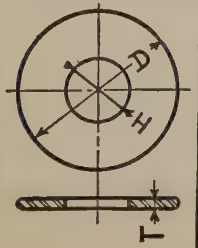

FLAT
OVAL
CUP
CONICAL

COUPLING BOLTS

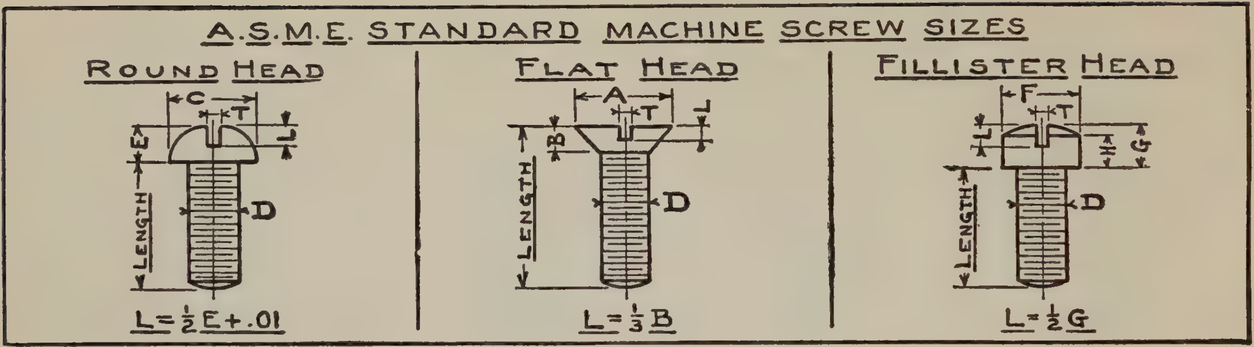
LENGTHS INCREASE BY 1/4"

DIAM OF BOLT	HEAD AND NUT SHORT DIAM.	HEAD AND NUT THICKNESS	STOCK LENGTHS
1/2	7/8	1/2	2–4 3/4
5/8	1 1/16	5/8	2–5
3/4	1 1/4	3/4	2 1/4–5 1/4
7/8	1 7/16	7/8	2 1/2–5 1/2
1	1 5/8	1	2 3/4–5 3/4
1 1/8	1 13/16	1 1/8	3–6
1 1/4	2	1 1/4	3 1/4–6

U.S. STANDARD CUT WASHERS



DIAMETER OF BOLT	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
H=HOLE	5/16	3/8	7/16	1/2	9/16	5/8	11/16	13/16	15/16	1 1/16	1 1/4	1 3/8	1 1/2	1 5/8
D=OUTSIDE DIAMETER	3/4	7/8	1	1 1/4	1 3/8	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2
T=THICKNESS	1/16	1/16	5/64	5/64	3/32	3/32	1/8	1/8	5/32	5/32	5/32	5/32	11/64	11/64



No.	0	1	2	3	4	5	6	7	8	9	10	12	14	16	18	20	22	24	26	28	30
D=Diam.	.060	.073	.086	.099	.112	.125	.138	.151	.164	.177	.190	.216	.242	.268	.294	.320	.346	.372	.398	.424	.450
A	.112	.138	.164	.190	.216	.242	.262	.294	.320	.346	.372	.424	.472	.528	.580	.632	.682	.732	.788	.840	.892
B	.029	.037	.045	.052	.060	.067	.075	.082	.090	.097	.105	.120	.135	.150	.164	.179	.194	.209	.224	.239	.254
C	.106	.130	.154	.178	.202	.226	.250	.274	.298	.322	.346	.394	.443	.491	.539	.587	.635	.683	.731	.779	.827
E	.042	.051	.060	.069	.078	.087	.096	.105	.114	.123	.133	.151	.169	.187	.205	.224	.242	.260	.278	.296	.315
F	.089	.110	.132	.153	.174	.196	.217	.238	.259	.281	.302	.345	.387	.430	.473	.515	.558	.601	.643	.686	.727
G	.049	.06	.072	.083	.095	.106	.118	.129	.141	.152	.163	.186	.209	.232	.255	.278	.301	.324	.346	.369	.402
H	.037	.046	.054	.063	.071	.080	.089	.097	.106	.114	.123	.140	.157	.174	.192	.209	.226	.243	.260	.277	.295
T	.025	.028	.030	.032	.034	.037	.039	.041	.043	.046	.048	.052	.057	.061	.066	.070	.075	.079	.084	.088	.093
Approx. Diam.	1/16	1/16	5/64	3/32	7/64	⅛	9/64	5/32	5/32	11/64	3/16	7/32	¼	17/64	9/32	5/16	11/32	⅜	⅜	27/64	7/16

NUMBER OF THREADS PER INCH AND DRILL SIZES FOR A. S. M. E. MACHINE SCREWS

The table below gives the number of threads per inch and proper body drill and tap drill sizes for A. S. M. E. standard and special machine screws. The numbers marked with an asterisk (*) are the A. S. M. E. special sizes. The tap drills allow for 75 per cent of a full thread. For description and diameter of number and letter drills see page 43.

Number	0	1	*1	2	*2	3	*3	4	*4	*4	5	*5	*5	6	*6	*6
Threads per inch	80	72	64	64	56	56	48	48	40	36	44	40	36	40	36	32
Body Drill	51	48	48	42	42	37	37	31	31	31	29	29	29	27	27	27
Tap Drill	56	53	54	50	51	46	47	43	44	45	38	39	40	33	34	36

Number	7	*7	*7	8	*8	*8	9	*9	*9	10	*10	*10	12	*12	14	*14
Threads per inch	36	32	30	36	32	30	32	30	24	30	32	24	28	24	24	20
Body Drill	22	22	22	18	18	18	13	13	13	9	9	9	1	1	¼″	¼″
Tap Drill	31	31	32	29	30	30	26	27	29	22	21	26	15	17	7	11

Number	16	*16	18	*18	20	*20	22	*22	24	*24	26	*26	28	*28	30	*30
Threads per inch	22	20	20	18	20	18	18	16	16	18	16	14	14	16	14	16
Body Drill	1	1	$\frac{19}{64}$″	$\frac{19}{64}$″	P	P	S	S	⅜″	⅜″	$\frac{13}{32}$″	$\frac{13}{32}$″	$\frac{7}{16}$″	$\frac{7}{16}$″	$\frac{29}{64}$″	$\frac{29}{64}$″
Tap Drill	2	3	C	B	H	H	L	K	N	O	Q	P	S	T	V	W

GROUP I—MACHINE FASTENINGS

SPECIFICATION—PROBLEM 1

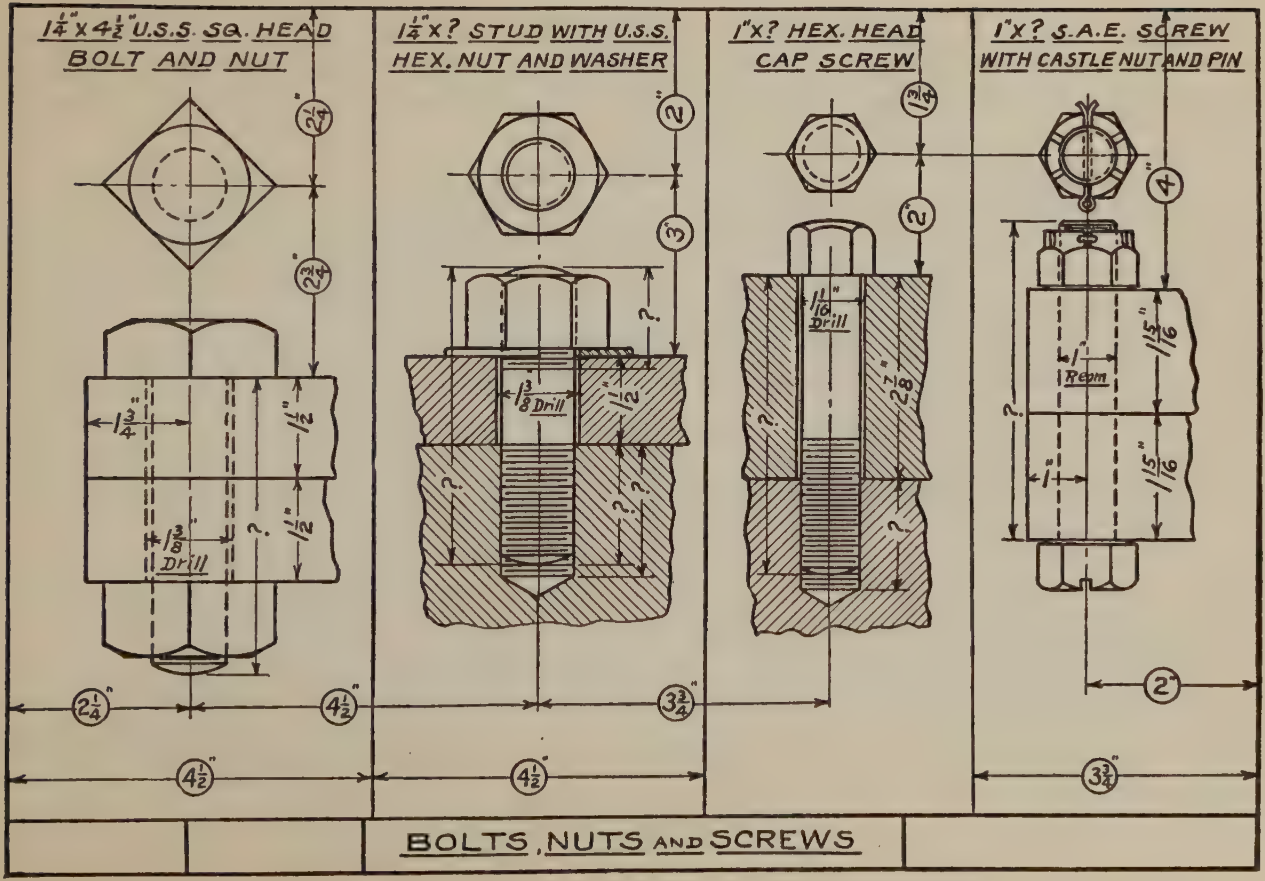
Make a complete drawing of the Bolts, Nuts, and Screws as shown on the lay-out sheet, page 29. Scale 12 inches equals 1 foot. Show only those dimensions given and those labeled with a question mark, as the sizes of heads, nuts, etc., need not be dimensioned on standard bolts and screws. Do not show the location dimensions which are enclosed in a circle.

Before drawing this plate, study the description of standard bolts and screws on pages 18, 19, and 20. For dimensions of U. S. S. bolts and nuts, see page 22. Dimensions of U. S. S. washers are given on page 25. Cap-screw sizes are given on page 23, and sizes for S. A. E. screws and nuts on page 24.

When a stud or a cap-screw is used in cast iron, the length of the part that screws into the iron should be at least one and one-half times the diameter of the stud or screw. When used in steel, the length of the part that screws into the steel should be at least equal to the diameter. The threaded hole should be at least two threads deeper than the length of the part of the stud or screw that is turned into it. This is necessary because it is very difficult for the machinist to cut a full thread to the bottom of the hole. The bottom of a threaded hole should be drawn with the 30 degree triangle to an angle of 120 degrees, which is approximately the angle of a drill point.

In the conventional representation of standard bolts, screws, etc., the threads need not be drawn to the exact pitch but may be spaced to some convenient division on the scale. This is especially true when drawing small screws or fine threads. When the bolt or screw is of some standard proportion, the standard should be mentioned as, "U. S. S. Hex. Head Bolt and Nut." In the drawing of a bolt or screw of some special form or design, all of the parts must be dimensioned and the form and pitch of thread specified.

Note: Before work on this problem is begun all text matter preceding it should be studied thoroughly.


1¼" x 4½" U.S.S. SQ. HEAD BOLT AND NUT
2¼"
2¾"
1¾"
1½"
1½"
1⅜" Drill
?
2¼"
4½"
4½"
1¼" x ? STUD WITH U.S.S. HEX. NUT AND WASHER
2"
3"
?
1⅜ Drill
1½"
?
?
?
?
3¾"
4½"
1" x ? HEX. HEAD CAP SCREW
1¾"
2"
1 1/16" Drill
2⅞"
?
?
?
1" x ? S.A.E. SCREW WITH CASTLE NUT AND PIN
4"
1 5/16"
1 5/16"
1" Ream
1"
?
2"
3¾"
BOLTS, NUTS AND SCREWS

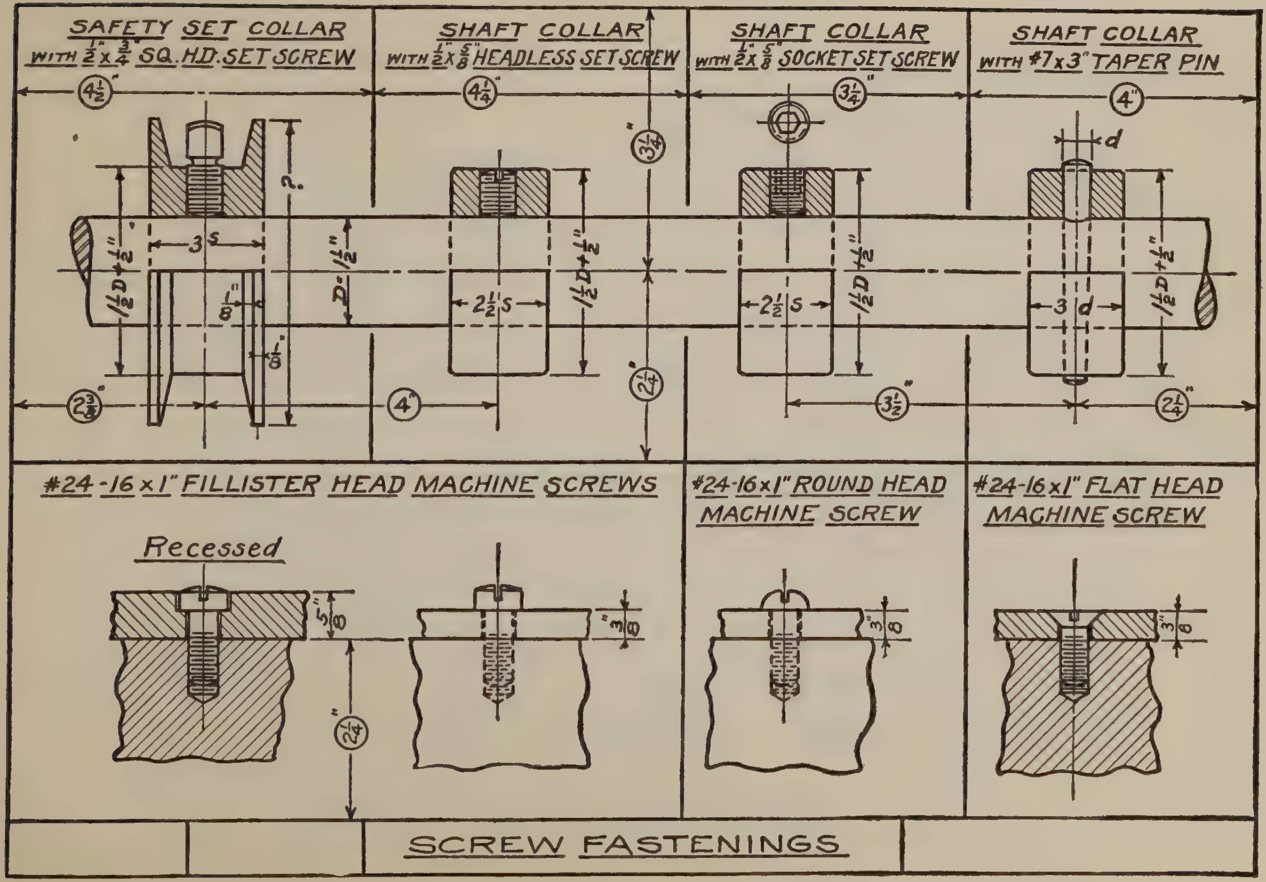
SPECIFICATION—PROBLEM 2

Make a complete drawing of the Screw Fastenings as shown on the lay-out sheet, page 31. Show only the dimensions that are indicated and the depth of the tapped holes for the machine screws. Scale 12 inches equals 1 foot.

The drawing on the upper half of the sheet represents a shaft with three set-collars held to the shaft with set-screws and one set-collar secured with a taper pin. Set-collars are used to keep shafts from moving in an axial direction and also to keep parts, such as loose pulleys, from moving in an axial direction on the shaft. The outside diameter of the flanges on the safety set-collar must be made such that the head of the set-screw does not project beyond it. The width of set-collars is commonly made two and one-half to three times the diameter of the set-screw used. To obtain the appropriate size of set-screws for a given shaft diameter, use the following empirical formula in which S equals the diameter of screw and D the diameter of shaft: $S = \frac{D}{8} + \frac{5}{16}$ inch. The *oval* point on set-screws has been found by experiment to have greater holding power than the other forms of points. See pages 20 and 25 for description and drawing of set-screws.

Taper pins form a convenient means of fastening collars, light gears, levers, etc. to shafts. They are a standard article. The sizes are designated by numbers. To determine the diameter of taper pin to use, take one-fourth to one-third of the shaft diameter and use standard size nearest to the result. See page 42 for sizes.

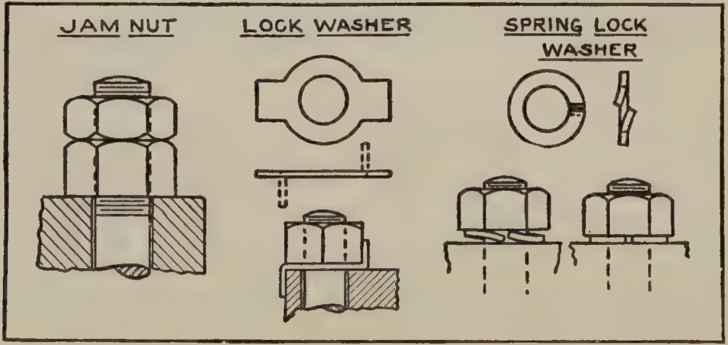
Machine screws are a form of cap screw which are very convenient for work requiring screws less than ¼ inch in diameter. They must always be labeled with the size-number, the number of threads per inch, and the length. The fillister head may be recessed or set in as shown. For description and sizes of machine screws see pages 19 and 26.

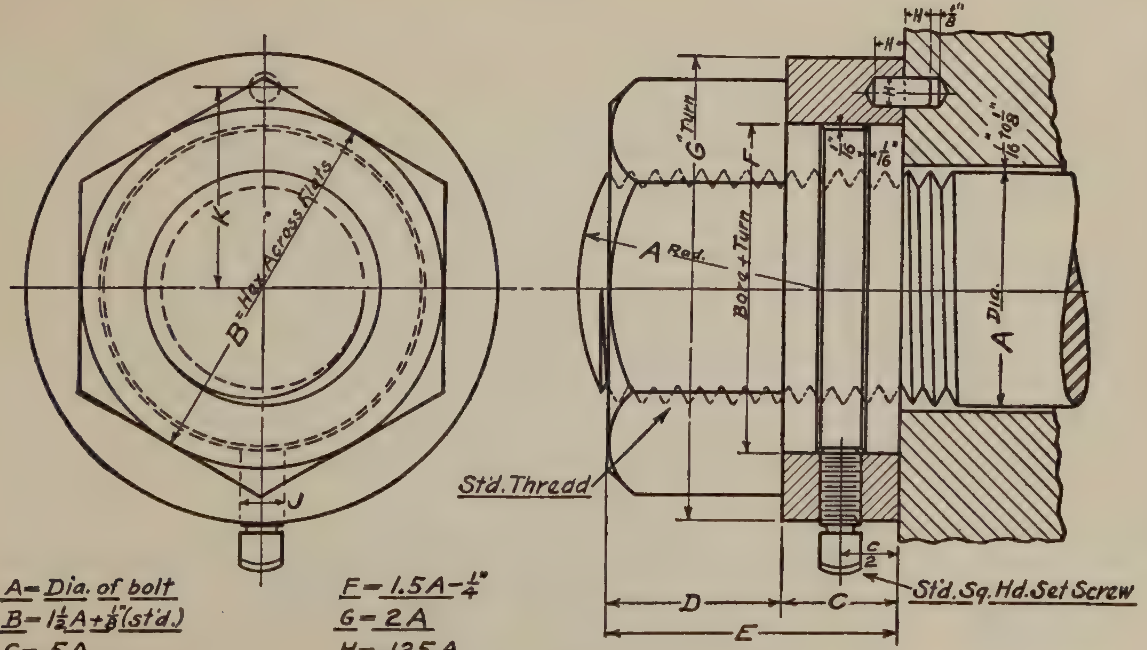

SAFETY SET COLLAR
WITH 1/2" x 3/4" SQ. HD. SET SCREW
SHAFT COLLAR
WITH 1/2" x 5/8" HEADLESS SET SCREW
SHAFT COLLAR
WITH 1/2" x 5/8" SOCKET SET SCREW
SHAFT COLLAR
WITH #7 x 3" TAPER PIN
4 1/2"
4 1/4"
3 1/4"
4"
3 1/4"
?
3 S
1 1/2 D + 1/2"
D = 1 1/2"
1/8"
1/8"
2 1/2 S
1 1/2 D + 1/2"
2 1/2 S
1 1/2 D + 1/2"
d
3 d
1 1/2 D + 1/2"
2 3/8"
4"
2 1/4"
3 1/2"
2 1/4"
#24-16 x 1" FILLISTER HEAD MACHINE SCREWS
Recessed
5/8"
3/8"
2 1/4"
#24-16 x 1" ROUND HEAD MACHINE SCREW
3/8"
#24-16 x 1" FLAT HEAD MACHINE SCREW
3/8"
SCREW FASTENINGS

SPECIFICATION—PROBLEM 3

Make a drawing consisting of two views of a Lock Nut as shown on the lay-out sheet, page 33, for one of the following bolt diameters: 3 inches, 3½ inches, 3¾ inches. Scale 12 inches equals 1 foot. Omit the formulae and insert proper dimensions on the drawing in place of letters.

Since nuts are fitted to turn freely, they have a tendency to unscrew, especially when they are subject to vibration. Many devices have been originated to prevent their unscrewing, a few of which are shown below. The lock nut in this problem is sometimes called a collar nut. It is used very successfully in heavy work. A portion of the hexagonal nut equal to *C* is turned cylindrical, and upon the surface a groove is cut. The cylindrical part of the nut fits into a collar. The collar is prevented from turning by a dowel pin as shown in the drawing. A set-screw fitted into the collar prevents relative motion between the nut and the collar. The groove is to take care of ridges which occur when the set-screw is tightened frequently and which might cause the nut to turn hard in the collar when adjustments are made.





A = Dia. of bolt
B = 1½A + 1/8" (std.)
C = .5A
D = .75A
E = 1.25A

F = 1.5A − 1/4"
G = 2A
H = .125A
J = .125A + 1/8" (nearest 1/16")
K = $\frac{F+G}{4}$

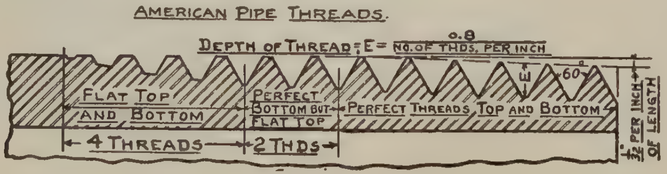
LOCK NUT

PIPING

Pipe is made of a variety of materials and is used for many purposes. The most familiar kind, and one that is commonly used for conveying gas, water, and steam, is known as wrought pipe. It is made of wrought iron or steel, altho steel pipe is most commonly used. The sizes of this pipe and the threads for connecting it have been standardized. Dimensions for American Standard pipe are given on page 35. Wrought pipe is known by its nominal inside diameter altho the nominal size differs from the actual inside diameter by varying amounts. Standard pipe is used for pressures under 125 pounds per square inch. For higher pressures, "extra strong" and "double extra strong" wrought pipe are used. These pipes have the same outside diameter for a given size as standard pipe but the inside diameter is reduced, making the walls thicker.

Pipe "fittings" are used to join or connect lengths of pipe. The smaller sizes of pipe usually have screwed joints. The pipe is threaded on the ends and connected with threaded fittings. The larger sizes of pipe are usually connected by means of flanges and flanged fittings bolted together.

Both external and internal pipe threads are cut on a taper of ¾ inch per foot as illustrated below. Because of this taper, the connections are leak-proof when screwed up properly.

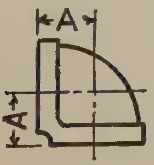

AMERICAN PIPE THREADS.
DEPTH OF THREAD = E = $\frac{0.8}{\text{NO. OF THDS. PER INCH}}$
E
60°
FLAT TOP AND BOTTOM
PERFECT BOTTOM BUT FLAT TOP
PERFECT THREADS TOP AND BOTTOM
4 THREADS
2 THDS
$\frac{1}{32}$ PER INCH OF LENGTH

DIMENSIONS OF STANDARD WROUGHT PIPE

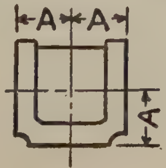
Nominal size	⅛	¼	⅜	½	¾	1	1¼	1½	2	2½	3
Inside diameter	.269	.364	.493	.622	.824	1.049	1.380	1.610	2.067	2.469	3.068
Outside diameter	.405	.540	.675	.840	1.050	1.315	1.660	1.900	2.375	2.875	3.500
Threads per inch	27	18	18	14	14	11½	11½	11½	11½	8	8
Tap drill	21/64	29/64	19/32	23/32	15/16	1 3/16	1 15/32	1 23/32	2 3/16	2 11/16	3 5/16

DIMENSIONS OF PITTSBURGH PIPING & EQUIPMENT CO. CAST IRON SCREWED PIPE FITTINGS

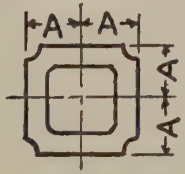
Size of pipe	¼	⅜	½	¾	1	1¼	1½	2	2½	3
A	13/16	15/16	1⅛	1 5/16	1 7/16	1¾	1 15/16	2¼	2 11/16	3⅛
B	¾	13/16	⅞	1	1⅛	1 5/16	1 7/16	1 11/16	1 15/16	2 3/16
C	...	...	1⅞	2¼	2¾	3¼	3 13/16	4½	5 3/16	6⅛
D	...	...	⅝	¾	¾	1	15/16	1¼	1 1/16	1¾
E	.91	1.14	1.35	1.64	1.96	2.4	2.74	3.34	3.93	4.62
T	⅜	7/16	½	9/16	21/32	23/32	25/32	⅞	15/16	1 1/32
G	⅛	5/32	3/16	7/32	7/32	¼	¼	¼	¼	9/32



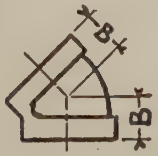
90° ELL



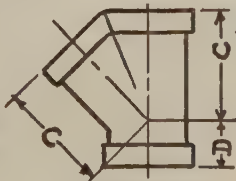
TEE



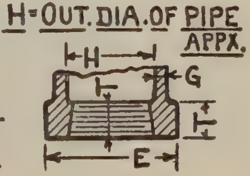
CROSS



45° ELL



LATERAL



SPECIFICATION—PROBLEM 4

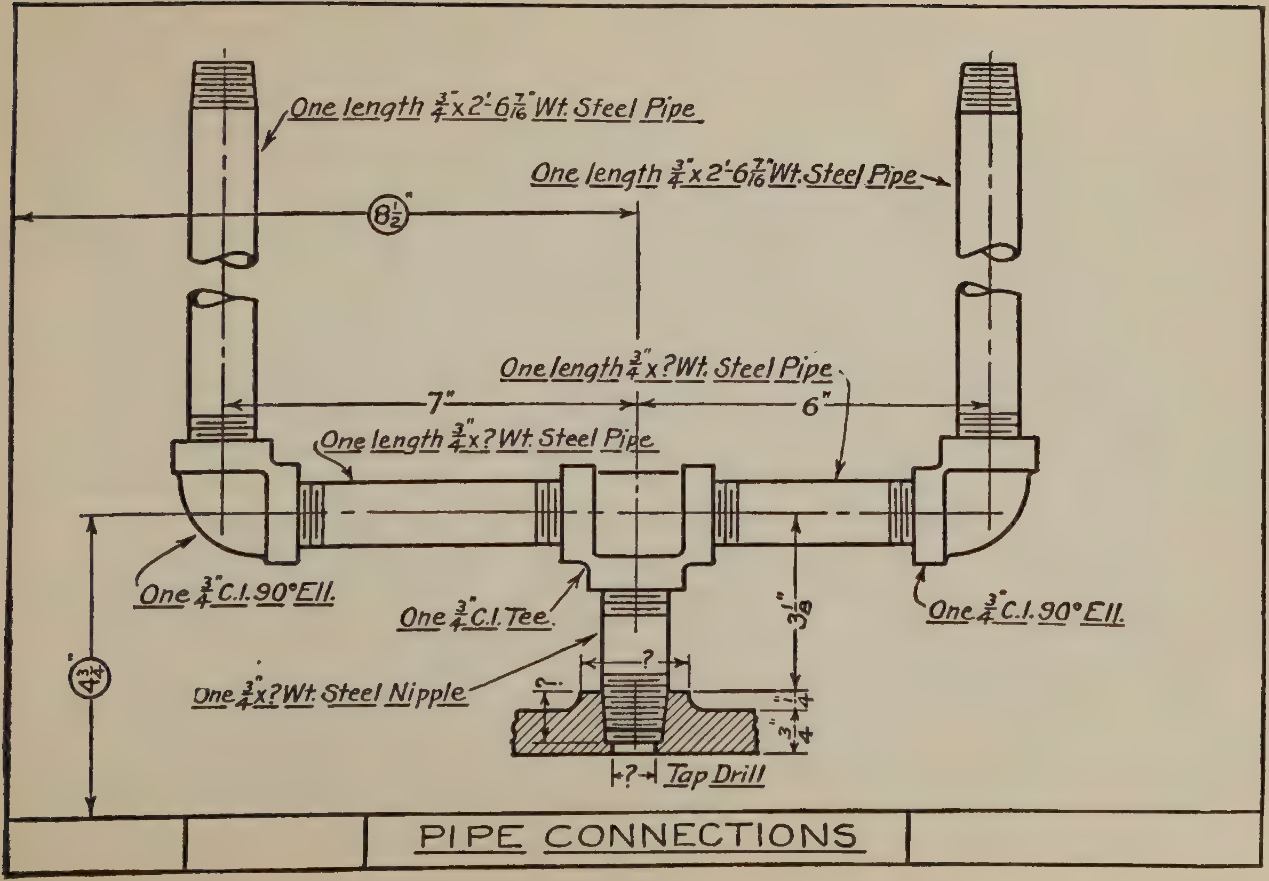
Make a drawing of the pipe connections exercise as shown on the lay-out sheet, page 37. Scale 12 inches equals 1 foot. Specify the nominal size and the length of each piece of pipe; also the nominal size and name of each fitting. As some fittings are made of malleable iron, it is necessary to specify that the fittings are of cast-iron. In computing the lengths of the pieces of pipe, consult the table below which gives the distance that a pipe enters a fitting when it is screwed up tight. The table also gives the proper total lengths of threads on pipe which may be used for the depth of holes tapped for pipe thread. Very short pieces of standard pipe, threaded on each end, are called "nipples."

The sizes of fittings may be taken from table of dimensions of screwed fittings on page 35. The inside diameter of a fitting (*H*) equals approximately the outside diameter of the pipe that screws into it. The thickness of the walls (*G*) is the same for all fittings.

The lay-out sheet shows the conventional method of drawing pipe threads. The taper of the threads which is 1/32 inch per inch of length on each side is usually exaggerated in drawings of pipe threads so that they are easily distinguished from straight threads.

TOTAL LENGTH OF PIPE THREADS AND DISTANCE PIPE SCREWS INTO FITTING

Size of pipe	⅛	¼	⅜	½	¾	1	1¼	1½	2	2½	3
Total length of thread	13/32	⅝	⅝	13/16	13/16	1 1/32	1 1/16	1 1/16	1 7/64	1⅝	1 11/16
Distance pipe screws into fitting	3/16	5/16	5/16	13/32	13/32	½	9/16	9/16	19/32	29/32	1

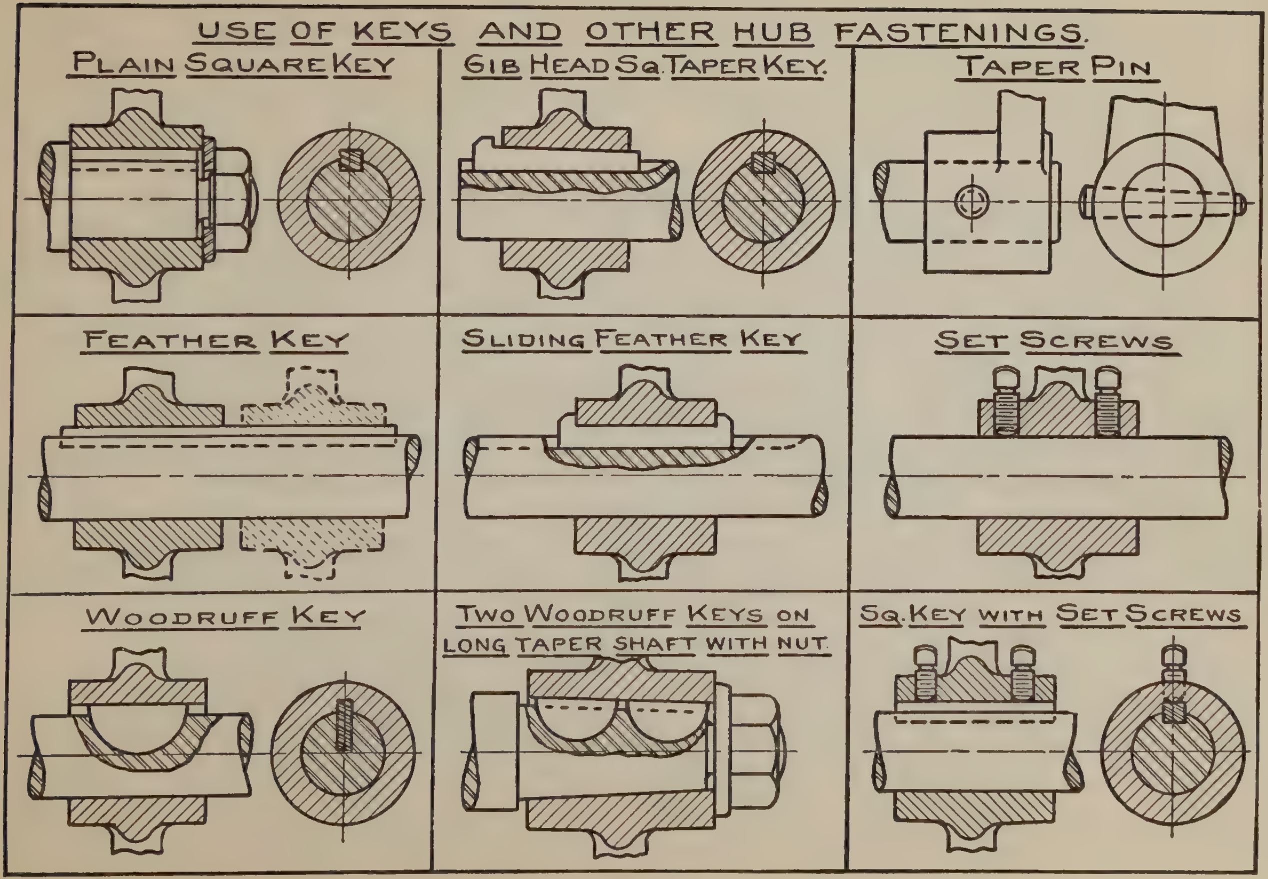

One length ¾" x 2'-6 7/16" Wt. Steel Pipe
One length ¾" x 2'-6 7/16" Wt. Steel Pipe
8½"
One length ¾" x ? Wt. Steel Pipe
7"
6"
One length ¾" x ? Wt. Steel Pipe
One ¾" C.I. 90° Ell.
One ¾" C.I. Tee.
One ¾" C.I. 90° Ell.
3⅛"
4¾"
?
?
¼"
¾"
One ¾" x ? Wt. Steel Nipple
? Tap Drill
PIPE CONNECTIONS

KEYS AND OTHER HUB FASTENINGS

The principal function of keys and pins is to prevent relative rotary motion between pulleys, gears, levers, etc. and the shafts on which they are mounted. The types of keys most commonly used in machine construction for fixed hubs have a rectangular cross section and are known as square, and flat keys. They engage a groove or slot formed both in the shaft and the hub of the pulley or gear and hence sometimes are termed "sunk keys." The grooves are known as key-seats. There is no universal standard among manufacturers as to the use and size of these keys altho it is customary to proportion them with relation to the shaft diameter. Average practice is to use a square key for shafts up to about 5 inches and a flat key for larger shafts. Square and flat keys are made either "straight" or "tapered." A straight key has opposite sides parallel, and tapered key has its top side only tapered ⅛ inch per foot. When a tapered key is used the key-seat in the hub must be cut to correspond to the tapered side of the key. Due to the wedging action when driven in place, it assists in preventing axial movement of the hub on the shaft. Taper keys are sometimes made with a hook or "gib-head" added to the large end. The gib-head key is used in places where it is inconvenient to drive out a key from the small end. See page 40.

The Woodruff key, which is patented, is a part of a circular disk. It is used extensively in machine tool practice in place of the square key, an advantage claimed over the square key being that it offers better resistance to deformation due to the turning over tendency of the forces to which a key is subjected. See pages 41 and 42.

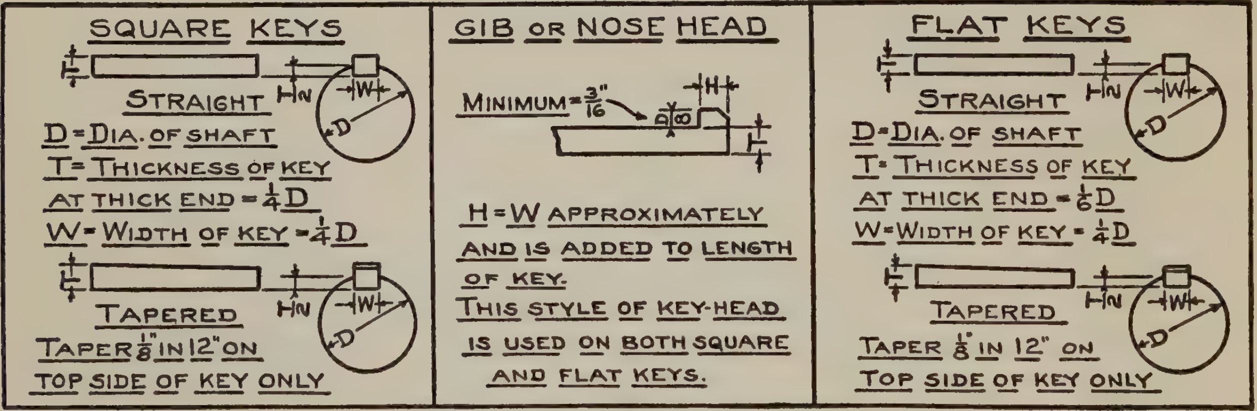
The feather key is used where a free axial movement of the hub along the shaft is desired. It is fastened to either the hub or the shaft, while the key-way in the other part is made a sliding fit. Sometimes feather keys are made integral or a part of the shaft as in the case of automobile transmission shafts. They are then known as splines. See pages 39 and 42.


USE OF KEYS AND OTHER HUB FASTENINGS.
PLAIN SQUARE KEY
GIB HEAD SQ. TAPER KEY.
TAPER PIN
FEATHER KEY
SLIDING FEATHER KEY
SET SCREWS
WOODRUFF KEY
TWO WOODRUFF KEYS ON LONG TAPER SHAFT WITH NUT.
SQ. KEY WITH SET SCREWS

SQUARE AND FLAT KEYS

The formulae given below represent average practice in proportioning square and flat keys. The square key is used for shafts below 5 inches in diameter and the flat key for larger sizes.

The table below gives key-seat dimensions for shafting and all articles to be attached, such as pulleys, sprockets, couplings, gears, etc., as used by The Fairbanks Co. in their appliances for the mechanical transmission of power.



KEYSEAT DIMENSIONS

Shaft Sizes, Inches	Width and Depth, Inches	Shaft Sizes, Inches	Width and Depth, Inches	Shaft Sizes, Inches	Width and Depth, Inches
¾ to ⅞	³⁄₁₆ x ³⁄₃₂	2⁷⁄₁₆ to 2⅝	⅝ x ⁵⁄₁₆	4³⁄₁₆ to 4⅝	1⅛ x ½
¹⁵⁄₁₆ “ 1⅛	¼ x ⅛	2¹¹⁄₁₆ “ 2⅞	¹¹⁄₁₆ x ¹¹⁄₃₂	4¹¹⁄₁₆ “ 5⅜	1¼ x ½
1³⁄₁₆ “ 1⅜	⁵⁄₁₆ x ⁵⁄₃₂	2¹⁵⁄₁₆ “ 3⅛	¾ x ⅜	5⁷⁄₁₆ “ 5⅝	1⅜ x ½
1⁷⁄₁₆ “ 1⅝	⅜ x ³⁄₁₆	3³⁄₁₆ “ 3⅜	¹³⁄₁₆ x ¹³⁄₃₂	5¹¹⁄₁₆ “ 6⅞	1½ x ⅝
1¹¹⁄₁₆ “ 1⅞	⁷⁄₁₆ x ⁷⁄₃₂	3⁷⁄₁₆ “ 3⅝	⅞ x ⁷⁄₁₆	6¹⁵⁄₁₆ “ 7⅞	1¾ x ¾
1¹⁵⁄₁₆ “ 2⅛	½ x ¼	3¹¹⁄₁₆ “ 3⅞	¹⁵⁄₁₆ x ¹⁵⁄₃₂	7¹⁵⁄₁₆ “ 8⅞	2 x ¾
2³⁄₁₆ “ 2⅜	⁹⁄₁₆ x ⁹⁄₃₂	3¹⁵⁄₁₆ “ 4⅛	1 x ½		

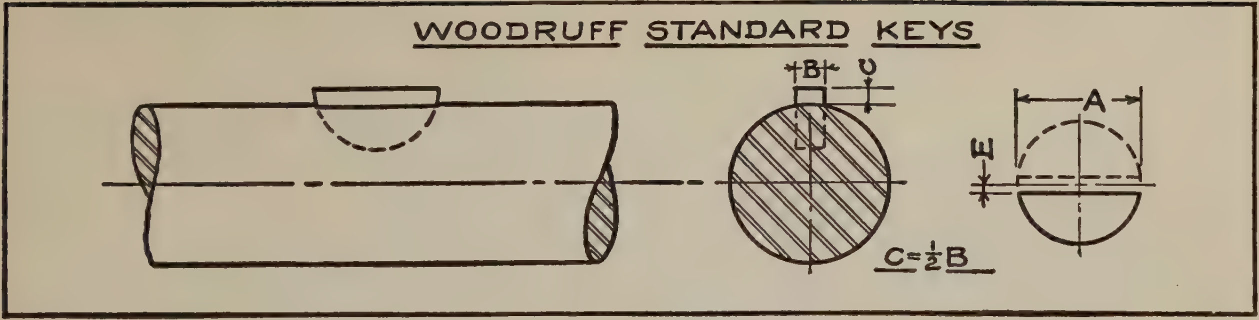
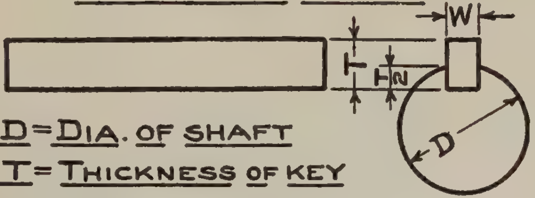


TABLE OF KEY DIMENSIONS

No. of Key	Dia. of Key A	Width of Key B	Center to Top E	No. of Key	Dia. of Key A	Width of Key B	Center to Top E	No. of Key	Dia. of Key A	Width of Key B	Center to Top E
1	½	1/16	3/64	12	⅞	7/32	1/16	20	1¼	7/32	5/64
2	½	3/32	3/64	A	⅞	¼	1/16	21	1¼	¼	5/64
3	½	⅛	3/64	13	1	3/16	1/16	D	1¼	5/16	5/64
4	⅝	3/32	1/16	14	1	7/32	1/16	E	1¼	⅜	5/64
5	⅝	⅛	1/16	15	1	¼	1/16	22	1⅜	¼	3/32
6	⅝	5/32	1/16	B	1	5/16	1/16	23	1⅜	5/16	3/32
7	¾	⅛	1/16	16	1⅛	3/16	5/64	F	1⅜	⅜	3/32
8	¾	5/32	1/16	17	1⅛	7/32	5/64	24	1½	¼	7/64
9	¾	3/16	1/16	18	1⅛	¼	5/64	25	1½	5/16	7/64
10	⅞	5/32	1/16	C	1⅛	5/16	5/64	G	1½	⅜	7/64
11	⅞	3/16	1/16	19	1¼	3/16	5/64				

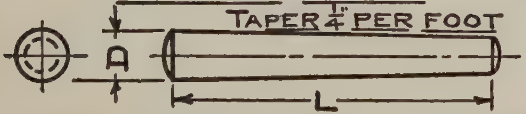
FEATHER KEYS



D = DIA. OF SHAFT
T = THICKNESS OF KEY
W = WIDTH OF KEY

D	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4
T	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{4}$
W	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1

TAPER PINS



L = MAXIMUM LENGTH OBTAINABLE.
MIN. LENGTH = $\frac{3}{4}$" LENGTHS INCREASE BY $\frac{1}{4}$"
DIA. OF PIN = $\frac{1}{4}$ TO $\frac{1}{3}$ DIA. OF ROD OR SHAFT

№	00	0	1	2	3	4	5	6	7	8	9	10
D	$\frac{9}{64}$	$\frac{5}{32}$	$\frac{11}{64}$	$\frac{3}{16}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{19}{64}$	$\frac{11}{32}$	$\frac{13}{32}$	$\frac{1}{2}$	$\frac{19}{32}$	$\frac{23}{32}$
L	$2\frac{1}{2}$	3	3	$3\frac{1}{2}$	$3\frac{1}{2}$	4	4	5	5	5	6	6

WOODRUFF KEYS SUITABLE FOR SHAFT DIAMETERS

DIA. OF SHAFT	NUMBER OF KEY	DIA. OF SHAFT	NUMBER OF KEY
$\frac{5}{16}-\frac{3}{8}$	1	$1\frac{3}{16}$	11, 13, 16
$\frac{7}{16}-\frac{1}{2}$	2, 4	$1\frac{1}{4}-1\frac{5}{16}$	12, 14, 17, 20
$\frac{9}{16}-\frac{5}{8}$	3, 5	$1\frac{3}{8}-1\frac{7}{16}$	14, 17, 20
$\frac{11}{16}-\frac{3}{4}$	3, 5, 7	$1\frac{1}{2}-1\frac{5}{8}$	15, 18, 21, 24
$\frac{13}{16}$	6, 8	$1\frac{11}{16}-1\frac{3}{4}$	18, 21, 24
$\frac{7}{8}-\frac{15}{16}$	6, 8, 10	$1\frac{13}{16}-2$	23, 25
1	9, 11, 13	$2\frac{1}{16}-2\frac{1}{2}$	25
$1\frac{1}{16}-1\frac{1}{8}$	9, 11, 13, 16		

DIAMETERS OF NUMBER AND LETTER DRILLS

Twist drills are made in *jobbers* sizes and in *number* and *letter* sizes. Jobbers sizes range from $\frac{1}{64}$ inch diameter upwards to very large drills and increase by even sixty-fourths of an inch. They are known by their actual diameter in inches. Number and letter drills are odd in size. The diameters are designated by numbers and letters and are given in the table below.

TABLE SHOWING NUMBER AND LETTER SIZES OF DRILLS

Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Dia. in inches	.2280	.2210	.2130	.2090	.2055	.2040	.2010	.1990	.1960	.1935	.1910	.1890	.1850	.1820	.1800	.1770

Number	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Dia. in inches	.1730	.1695	.1660	.1610	.1590	.1570	.1540	.1520	.1495	.1470	.1440	.1405	.1360	.1285	.1200	.1160

Number	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Dia. in inches	.1130	.1110	.1100	.1065	.1040	.1015	.0995	.0980	.0960	.0935	.0890	.0860	.0820	.0810	.0785	.0760

Number	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
Dia. in inches	.0730	.0700	.0670	.0635	.0595	.0550	.0520	.0465	.0430	.0420	.0410	.0400	.0390	.0380	.0370	.0360

Number	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Dia. in inches	.0350	.0330	.0320	.0310	.0292	.0280	.0260	.0250	.0240	.0225	.0210	.0200	.0180	.0160	.0145	.0135

Letter	A	B	C	D	E	F	G	H	I	J	K	L	M
Dia. in inches	.234	.238	.242	.246	.250	.257	.261	.266	.272	.277	.281	.290	.295

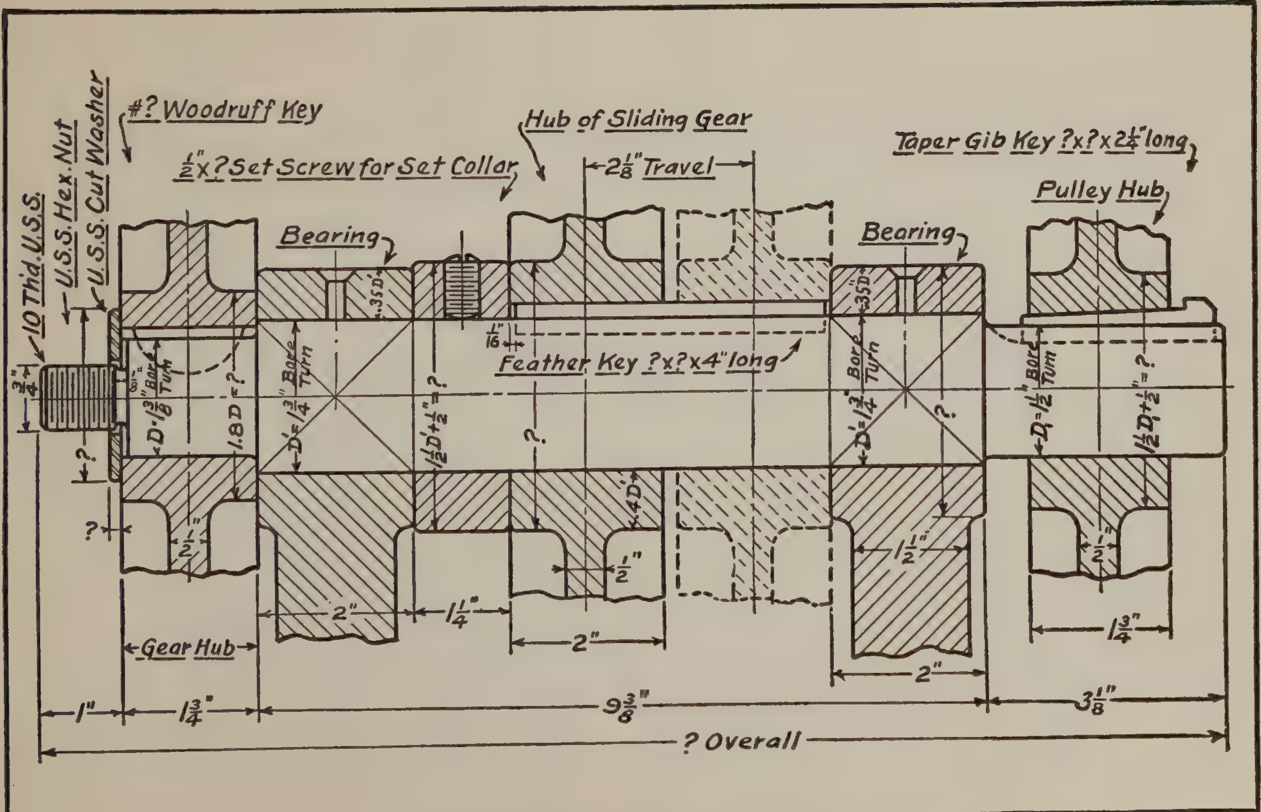
Letter	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Dia. in inches	.302	.316	.323	.332	.339	.348	.358	.368	.377	.386	.397	.404	.413

SPECIFICATION—PROBLEM 5

Make a complete drawing of the Application of Keys as shown on the lay-out sheet, page 45. Scale 12 inches equals 1 foot. Put in dimensions in place of question marks and actual sizes in place of the formulae. Determine the over all length of the shaft before starting to draw, so as to locate the drawing properly. The hexagon nut at the end of the shaft is to be drawn in place.

The drawing is an exercise in the proportioning of hubs and the selection of proper size keys. The shaft is mounted in two plain cast iron bearings, has a gear at one end held up against a shoulder with a nut and washer, a pulley on the other end and a sliding gear which is shown in dotted outline to indicate its extreme position when out of mesh. The proportions given for gear and pulley hubs represent good practice. Use the formulae on page 40 for selecting the proper size key for the pulley hub, and the tables on page 42 for the feather key and Woodruff key. In the table of suitable sizes of Woodruff keys for shaft diameters, several sizes of keys are given for a certain shaft diameter, but they are all the same thickness. If the hub is very long use two or more keys of the small size; otherwise use one key, of the larger sizes mentioned, that the length of the hub will accommodate nicely.

The light cross lines on the shaft indicate that these are bearing surfaces and that the shaft should be polished at these places. They are commonly used on drawings of shafts, especially when the shafts are drawn separately, or alone. The pulley end of the shaft is long enough to permit a slight axial adjustment of the pulley when belting to a motor or other unit. The fillets may be made ¼ inch radius; the roundings ⅛ inch radius. The oil holes are drilled ⅛ inch and are countersunk slightly with a 60 degree countersink.

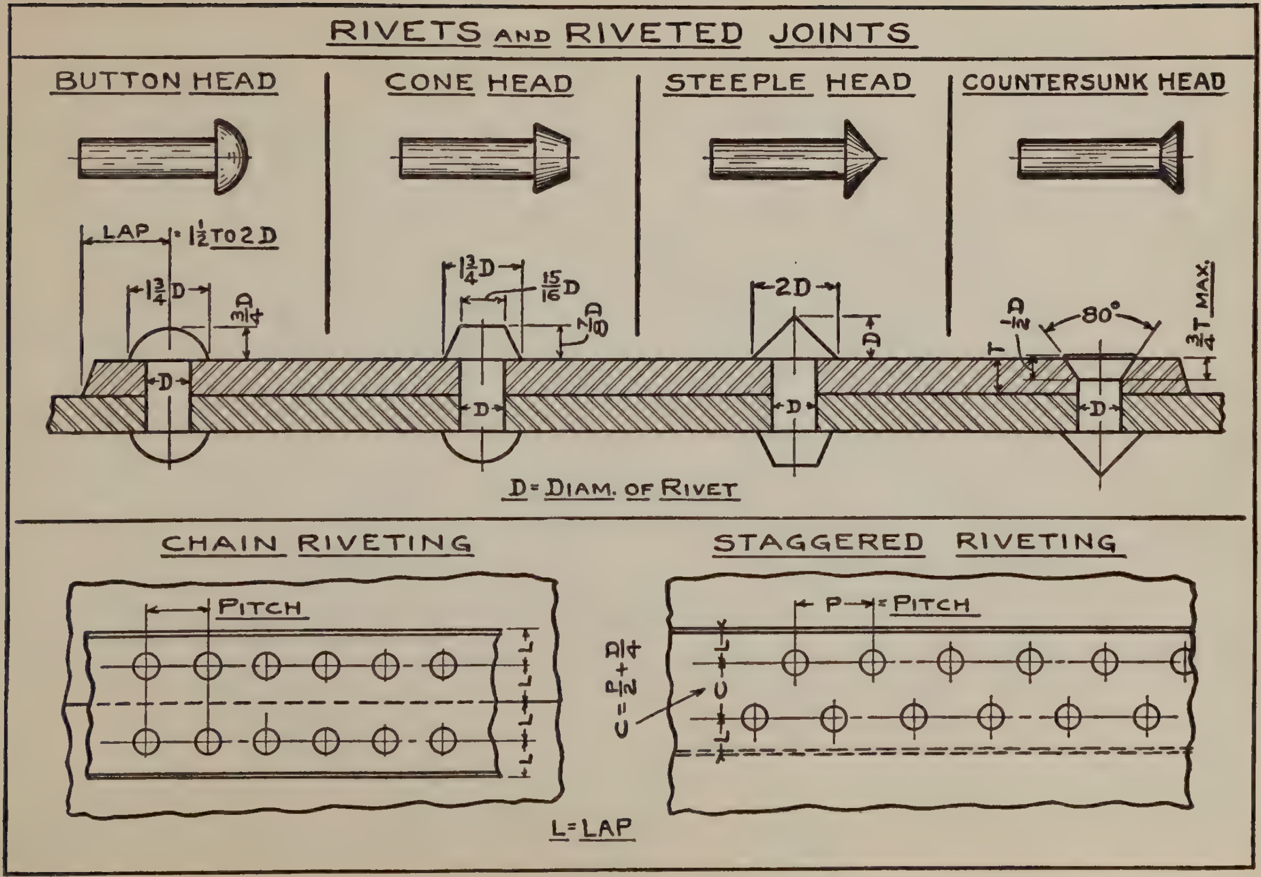


APPLICATION OF KEYS

RIVETS AND RIVETED JOINTS

The most common method of uniting plates in forming tanks, boilers, etc., and in connecting structural steel members as used in buildings and bridges is by means of rivets and riveted joints. A rivet, which is similar to a short bolt, consists simply of a head and shank. It is placed and held firmly in a hole which is either punched or drilled thru the plates or parts that are to be joined, and a second head is formed by upsetting the part of the shank that projects thru the hole. A special heading tool which is struck with a hand hammer or with a pneumatic hammer, is used for this purpose. On boiler and structural work, the rivets are heated before being driven and the holes are made from $\frac{1}{32}$ inch to $\frac{1}{16}$ inch larger than the diameter of the rivet.

Rivets or rivet blanks as they are sometimes called, are made of a very tough and ductile quality of iron or steel. They may be purchased in many sizes and lengths and with various forms of heads. For convenience, the head which is formed when making a joint, is called the "point" to distinguish it from the head on the rivet blank. The forms of heads most generally used are those illustrated on page 47. The proportions indicated are those used by the Champion Rivet Company. The button head type is widely used for points. The rivet must fill the hole after driving and the blank must be long enough to allow for this and for sufficient material to form the head. The length of rivets necessary for different thicknesses or "grips" may be obtained from manufacturers hand books on structural steel. For countersunk heads the countersink in the plate should never be more than three-fourths of the thickness of the plate and for that reason the head or point is apt to project a small amount. If the plate is required to be perfectly smooth the head or point is chipped off level with the surface of the plate.


RIVETS AND RIVETED JOINTS
BUTTON HEAD
CONE HEAD
STEEPLE HEAD
COUNTERSUNK HEAD
LAP = 1½ TO 2 D
1¾D
¾D
D
1¾D
15/16 D
7/8 D
D
2D
D
D
D/2
80°
T
¾T MAX.
D
D = DIAM. OF RIVET
CHAIN RIVETING
PITCH
L
L
L
L
STAGGERED RIVETING
P = PITCH
L
C
L
C = P/2 + D/4
L = LAP

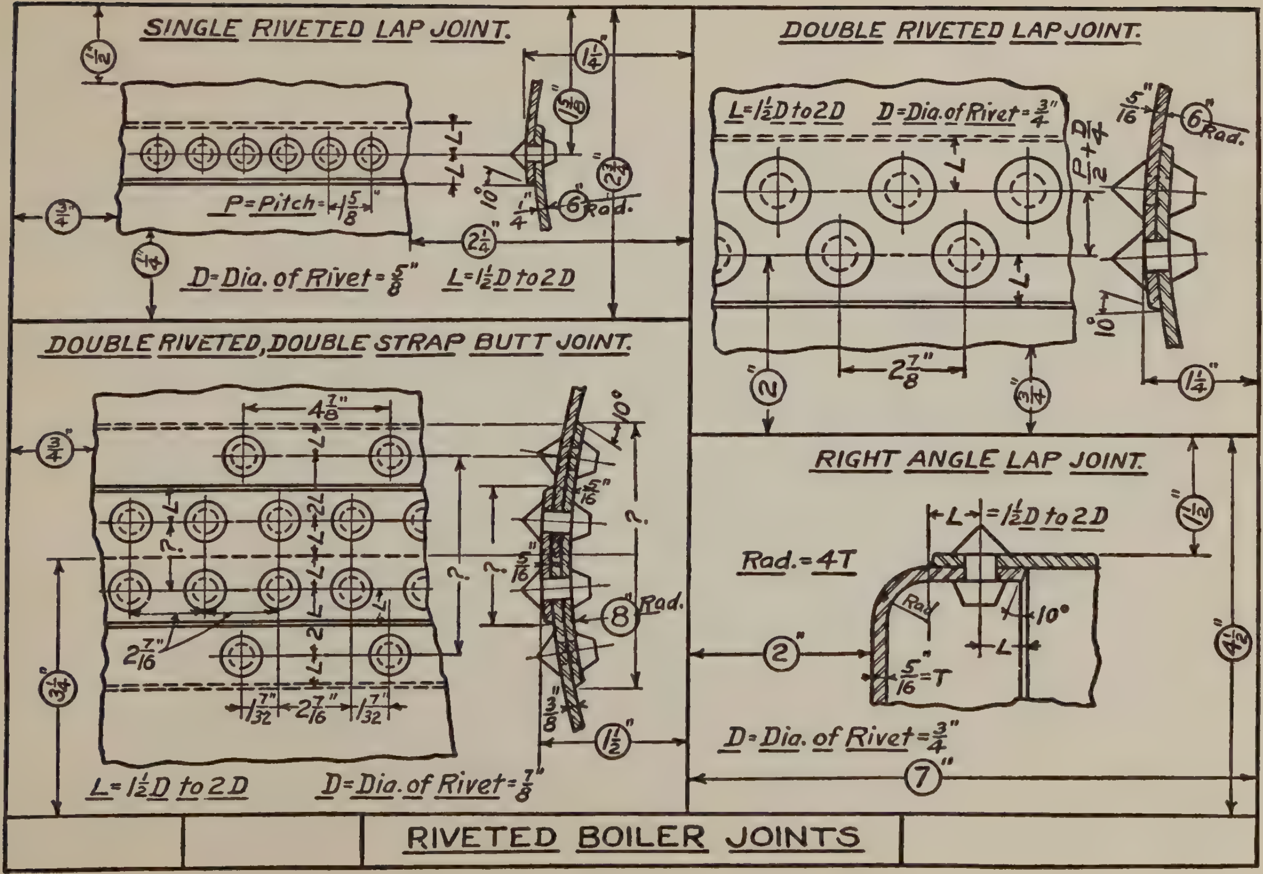
SPECIFICATION—PROBLEM 6

Make a complete drawing of the Riveted Boiler Joints, as shown on the lay-out sheet, page 49. Scale 6 inches equals 1 foot. Omit all letters and formulae and show exact sizes. Use 1½D for lap.

In a lap-joint the plates are overlapped and held together with one or more rows of rivets. The margin, measured from the center line of the rivets to the edge of the plate, is known as the lap and is generally made from one and one-half to two times the diameter of the rivet. If one row of rivets is used, the joint is said to be single riveted and with two rows the joint is said to be double riveted. In a double-riveted lap-joint the rivets may be arranged in two ways, namely, "staggered," or "chain riveted," see page 47. In a butt-joint, the plates to be joined butt against each other and are held in place by separate overlapping plates or straps.

The design of boilers and other pressure tanks is a special study. The thickness of the steel plate, the type of joint and the size and spacing of the rivets used, are determined by the requirements of the particular tank and must generally comply with State safety rules or insurance company regulations. The sizes given in this plate are taken from the Wisconsin Industrial Commission Code of Boiler design.

For many purposes, a riveted joint must be made leak tight as in the case of steam or water pressure tanks. To assist in this, a blunt chisel and a hammer are used to peen or force the edges of the plate close to the plate adjoining it. This is called "calking." It is made easier by cutting the edges of plates at an angle of from 10 to 15 degrees, before assembling.



RIVETED BOILER JOINTS

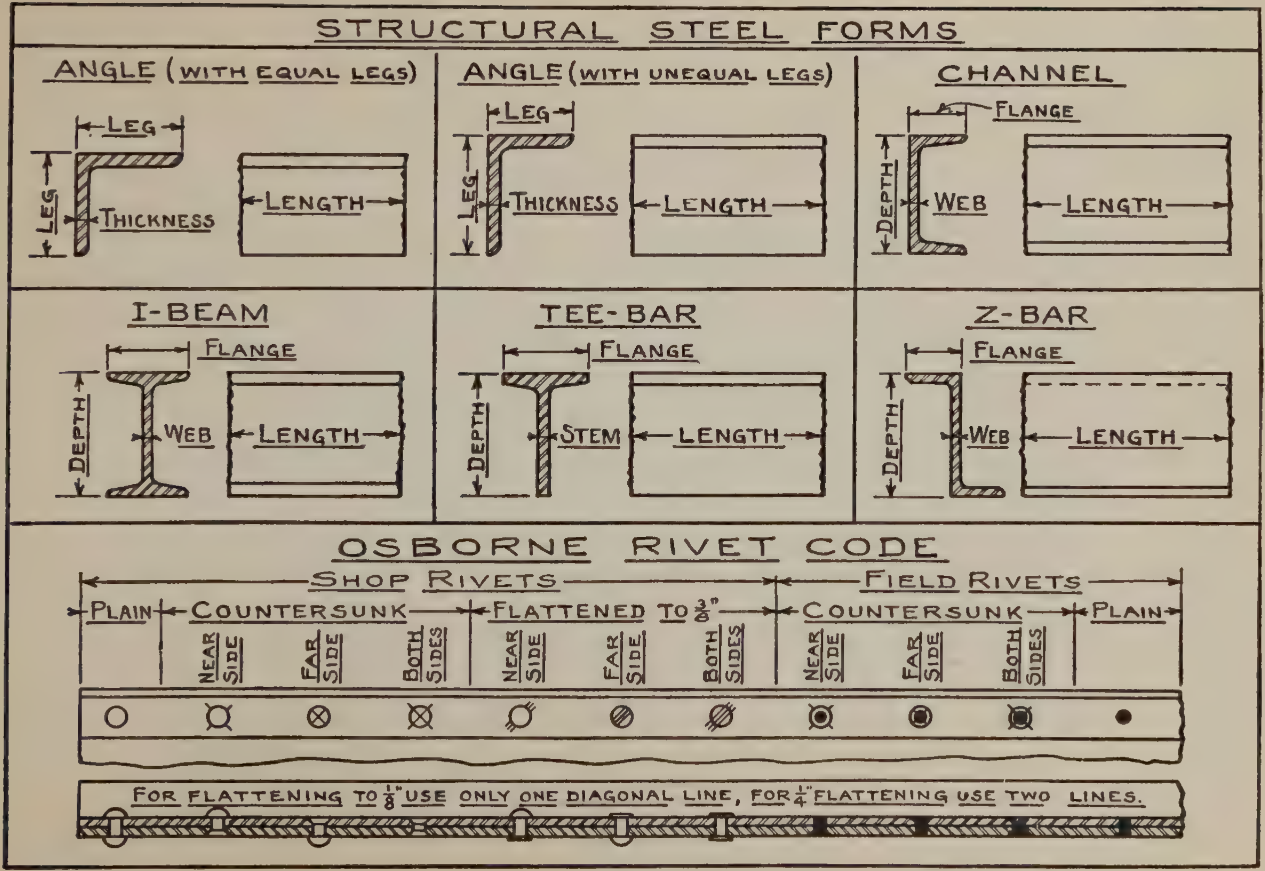
STRUCTURAL DRAWING

In the building of steel structures, bridges, cranes, etc., it has been found necessary to standardize the shapes and sizes of the various lengths of steel used to form the members. These lengths of steel, or rolled steel shapes, have names derived from their cross sectional forms. The metal in the cross sectional area is distributed and proportioned with a view to economy in carrying certain loads or forces. On page 51 are given some of the most important standard steel forms. The standard dimensions and properties of the different shapes and sizes may be obtained from handbooks issued by steel companies that manufacture them.

The design of structural work generally calls for the selection of the economical shape and size of members and the riveted connections for joining them required to transmit the forces given. Some of the connections have been standardized and are given in the handbooks on structural steel.

Structural work is usually assembled in the shop into units that are convenient to ship, and these units are then put together at the place of erection which is known as the "field." The Osborne rivet code on page 51 is used on drawings to distinguish between shop and field rivets, and to furnish other necessary information.

The rivets used in structural work are most generally "button-head," or countersunk. The point or head is sometimes flattened to allow for clearance. As structural drawings are often made to a very small scale, the lines are close to each other, and are drawn lighter than in the average machine drawing. Since the dimensions are often crowded, it is customary to draw dimension lines without a break in them and place the figures above the lines.


STRUCTURAL STEEL FORMS
ANGLE (WITH EQUAL LEGS)
LEG
LEG
THICKNESS
LENGTH
ANGLE (WITH UNEQUAL LEGS)
LEG
LEG
THICKNESS
LENGTH
CHANNEL
FLANGE
DEPTH
WEB
LENGTH
I-BEAM
FLANGE
DEPTH
WEB
LENGTH
TEE-BAR
FLANGE
DEPTH
STEM
LENGTH
Z-BAR
FLANGE
DEPTH
WEB
LENGTH
OSBORNE RIVET CODE
SHOP RIVETS
FIELD RIVETS
PLAIN
COUNTERSUNK
FLATTENED TO 3/8"
COUNTERSUNK
PLAIN
NEAR SIDE
FAR SIDE
BOTH SIDES
NEAR SIDE
FAR SIDE
BOTH SIDES
NEAR SIDE
FAR SIDE
BOTH SIDES
FOR FLATTENING TO 1/8" USE ONLY ONE DIAGONAL LINE, FOR 1/4" FLATTENING USE TWO LINES.

SPECIFICATION—PROBLEM 7

Make a complete drawing, consisting of three views, of the Column and Connections as shown on the lay-out sheet, page 53. Scale 3 inches equals 1 foot. The views are to be arranged as shown in the small enclosed "Layout of Plate." The picture drawing and lettered beam and angle sections are not to be drawn.

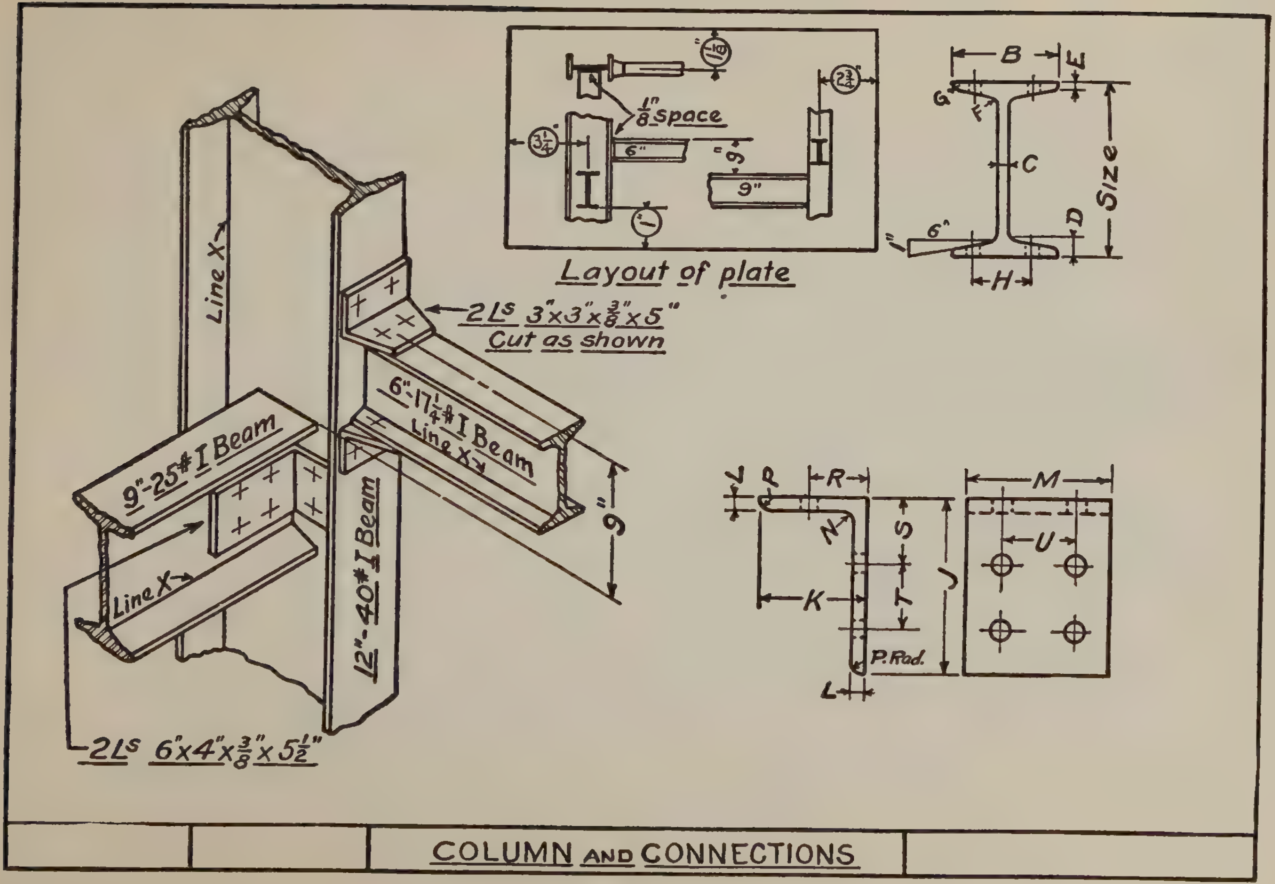
Do not show a line indicating the fillets of beam flanges. This line, marked "Line X," was put in the picture drawing to make it more clear. In this drawing it is assumed that the column is to be assembled in the shop and that the rivets are to be "plain" with button heads and points. See Osborne code, page 51. The sizes of angles and beams must be specified with a note as follows: Angles:—Number required, by length of leg, by thickness, by length; example 2Ls–8″x8″x½″x11″ long. Beams:—Number required, by depth, by weight per foot, by length; example 2Is–10″–30 lbs., 18′–6″ long. In this drawing, which is merely an exercise, the length of the beams can be assumed. The location of all rivet holes must be dimensioned carefully.

DIMENSIONS FOR I BEAMS (Taken from Cambria)

SIZE	WEIGHT	B	C	D	E	F	G	H	RIVET
6 inches	17¼ lbs.	3.57	.47	.49	.23	.33	.14	2	⅝
9 inches	25 lbs.	4.45	.41	.63	.29	.39	.17	2½	¾
12 inches	40 lbs.	5.21	.56	.74	.35	.45	.21	2¾	¾

DIMENSIONS FOR ANGLES (Taken from Cambria)

J	K	L	M	N	P	R	S	T	U
3	3	⅜	5	⁵⁄₁₆	⅜	1¾	1¾		See Beam
6	4	⅜	5½	½	⅜	2½	2½	2¼	3


Layout of plate
1 1/8"
2 3/4"
1/8" space
3 1/4"
6"
9"
9"
1"
B
E
G
F
C
Size
D
6"
1"
H
Line X
2L^s 3"x3"x3/8"x5"
Cut as shown
6"-17 1/4# I Beam
Line X
9"-25# I Beam
Line X
12"-40# I Beam
9"
2L^s 6"x4"x3/8"x5 1/2"
L
P
R
M
N
S
U
T
J
K
P. Rad.
L
COLUMN AND CONNECTIONS

SPECIFICATION—PROBLEM 8

Make an assembly drawing, consisting of two views, of the 2,000 gallon Storage Tank as shown on the lay-out sheet, page 55. Scale ¾ inch equals one foot. Include detail drawings of the longitudinal joint and the tank-end joint at a scale of 3 inches equals 1 foot. All rivets ¾ inch diameter unless otherwise specified. Do not show all rivets but draw only those shown in the lay-out sheet. The elliptical manhole and the pipe flanges need not be drawn very accurately and need not be dimensioned as these parts necessitate an extra detail drawing made to a larger scale. For sizes of the manhole and flanges, see Problem 9.

It will be observed that where the longitudinal seam meets the circumferential seam there is a thickness of three plates. These plates must be joined so as to maintain a tight joint. This is accomplished by thinning out one or more of the plates and is illustrated in Figure 1 below.

Tanks of this kind are used for storing oil and other liquids. The small sizes are made without a manhole and are often put together as shown in Figure 2 below.

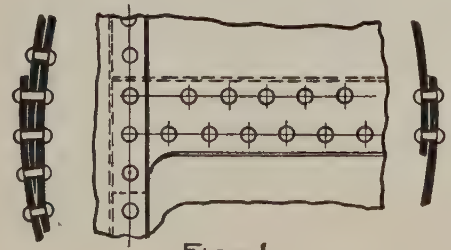


FIG.- 1.

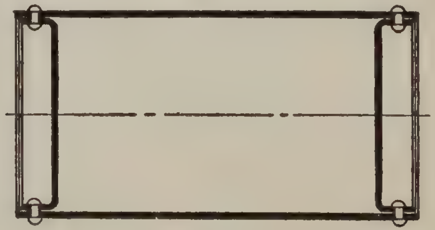
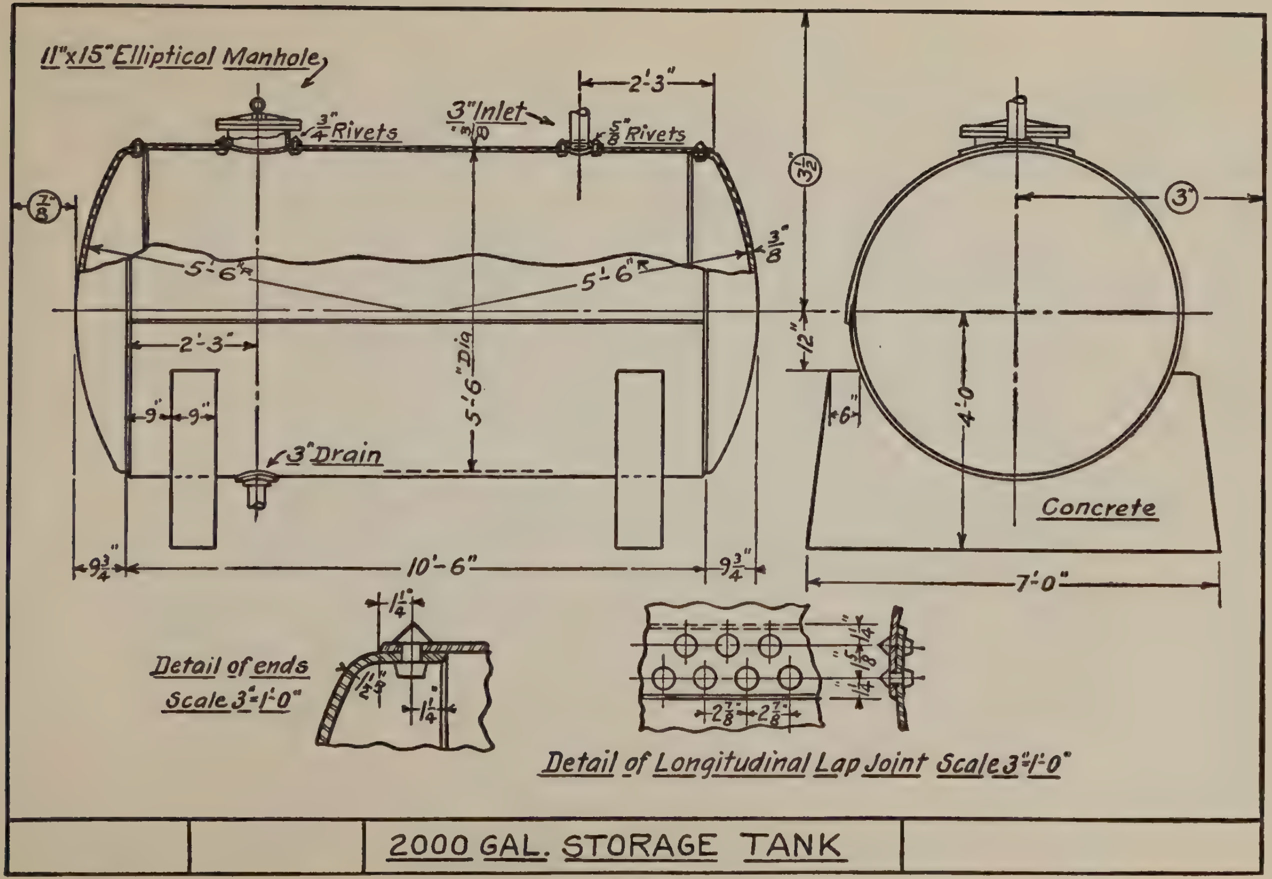


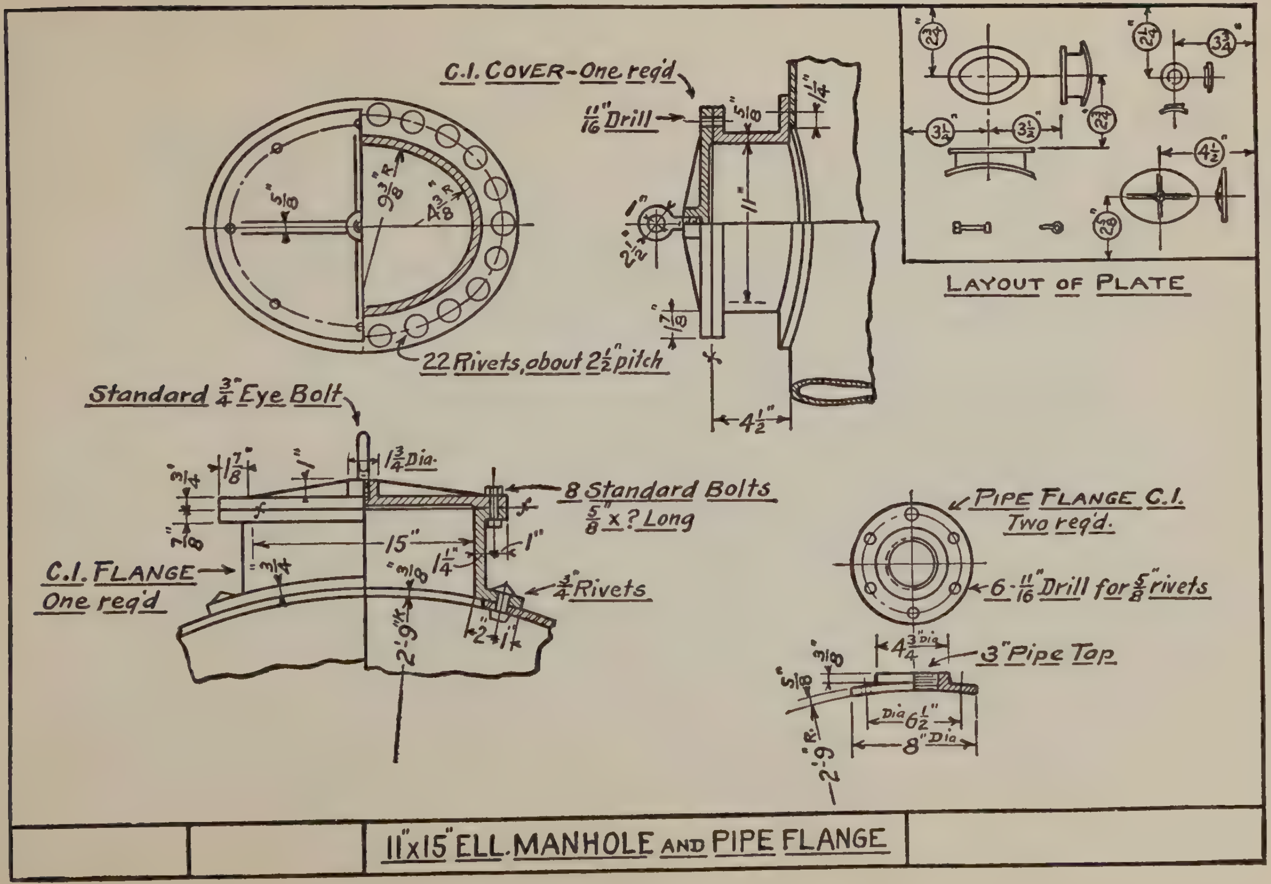
FIG.- 2.


11"x15" Elliptical Manhole
3/4" Rivets
3" Inlet
5/8" Rivets
2'-3"
7/8"
3 1/2"
3"
3/8"
5'-6"
5'-6"
2'-3"
5'-6" Dia
12"
9"
9"
3" Drain
6"
4'-0
Concrete
9 3/4"
10'-6"
9 3/4"
7'-0"
1 1/4"
1 1/2"
1 1/4"
Detail of ends
Scale 3"=1'-0"
1 1/4"
1 5/8"
1 1/4"
2 7/8"
2 7/8"
Detail of Longitudinal Lap Joint Scale 3"=1'-0"
2000 GAL. STORAGE TANK

SPECIFICATION—PROBLEM 9

Make complete detail drawings of the 11-inch by 15-inch Elliptical Manhole and Pipe Flange for 2,000 gallon storage tank. Scale 3 inches equals 1 foot. Each of the parts is to be drawn separately and the views arranged as shown on the small "Layout of Plate." Each part should be labeled with a sub-title giving the name of the part in inclined upper case letters, the number required and the material in lower case letters. The bolts are standard square head machine bolts with hexagon nuts and need not be drawn but must be specified. The eye-bolt which is drop-forged of steel, is also a standard article and need not be drawn but must be specified.

This manhole is used on top of the 2,000 gallon storage tank of Problem 8. It is necessary to have a hole in a tank of this kind so as to enable a man to enter the tank to assist in riveting the ends in place. It is also used for purposes of cleaning out the tank when necessary.


C.I. COVER - One req'd.
11/16" Drill
5/8"
1 1/4"
11"
1"
2 1/2"
1 7/8"
4 1/2"
5/8"
9 3/8" R
4 3/8" R
22 Rivets, about 2 1/2" pitch
LAYOUT OF PLATE
2 1/4"
3 1/2"
3 1/2"
2 1/4"
2 1/4"
3 3/4"
4 1/2"
2 5/8"
Standard 3/4" Eye Bolt
1 7/8"
3/4"
1"
1 3/4" Dia.
7/8"
8 Standard Bolts
5/8" x ? Long
15"
1"
1 1/4"
3/4"
5/8"
C.I. FLANGE
One req'd
3/4" Rivets
2'-9" R
2"
1"
PIPE FLANGE C.I.
Two req'd.
6 - 11/16" Drill for 5/8" rivets
4 3/4" Dia
3" Pipe Tap
3/8"
5/8"
Dia 6 1/2"
8" Dia
2'-9" R.
11"x15" ELL. MANHOLE AND PIPE FLANGE

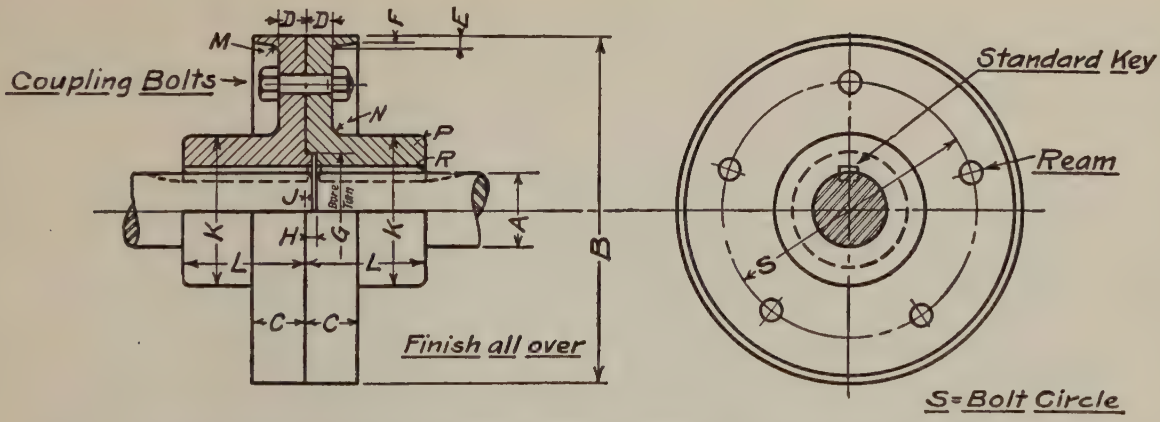
GROUP 2—APPLIANCES FOR TRANSMISSION OF POWER

SPECIFICATION—PROBLEM 10

Make an assembly working drawing, consisting of front and end views of a Flange Coupling for a 1½ inch diameter shaft. Scale 12 inches equals 1 foot. Any other size included in the table may be used and drawn to a suitable scale. Place proper dimensions in place of letters and select and indicate proper size of key. The table of sizes is not to appear on the finished drawing. It will be noticed that the upper half of the front view is drawn in section and that in the lower half the dotted lines are omitted. This is often done when the part drawn is symmetrical about the center line, as it shows clearly the inside construction and the outside appearance.

A coupling is a form of fastening used to connect adjoining shafts or other parts of machinery so that motion may be transmitted from one to the other. There are many forms of shaft couplings used for a variety of purposes. Some are designed for joining shafts that do not require frequent disconnection while others are so constructed as to permit the connected shafts to be released or uncoupled at will. The latter are commonly called clutches.

The coupling in the drawing is a very common type. It consists of two flanged hubs secured with keys to the ends of the shafts that are to be joined. A headless set-screw is often used in addition to the key. One of the flanges has a short cylindrical piece turned on its face to a diameter equal to *G* in the table. The other flange has a cylindrical recess bored in its face to the same diameter. When the flanges are bolted to each other these parts fit together and keep the shafts in perfect alignment. So that the shaft may enter the hub easily, the opening of the bore is slightly rounded with a radius equal to *R* in the table.



WESTINGHOUSE ELECTRIC AND MFG. CO. TABLE OF SIZES.

Nominal Bore.	Flange.								Hub.		Radii.				Bolts.			
A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	Dia.	Length	No. Req'd.
Up to 1" Incl.	$5\frac{1}{8}$	$\frac{7}{8}$	$\frac{7}{16}$	$\frac{5}{32}$	$\frac{1}{8}$	$1\frac{3}{4}$	$\frac{3}{32}$	$\frac{1}{16}$	2	2	$\frac{3}{16}$	$\frac{5}{16}$	$\frac{1}{16}$	$\frac{1}{32}$	$3\frac{1}{2}$	$\frac{3}{8}$	$1\frac{1}{4}$	5
$1\frac{1}{16}$" to $1\frac{1}{4}$" "	$5\frac{5}{8}$	$\frac{15}{16}$	$\frac{1}{2}$	$\frac{5}{32}$	$\frac{1}{8}$	2	$\frac{3}{32}$	$\frac{1}{16}$	$2\frac{1}{2}$	$2\frac{1}{4}$	$\frac{3}{16}$	$\frac{5}{16}$	$\frac{1}{16}$	$\frac{1}{32}$	4	$\frac{3}{8}$	$1\frac{3}{8}$	6
$1\frac{5}{16}$" to $1\frac{1}{2}$" "	$5\frac{7}{8}$	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{3}{16}$	$\frac{5}{32}$	$2\frac{1}{4}$	$\frac{3}{32}$	$\frac{1}{16}$	3	$2\frac{1}{2}$	$\frac{7}{32}$	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{1}{32}$	$4\frac{7}{8}$	$\frac{1}{2}$	$1\frac{3}{4}$	6
$1\frac{9}{16}$" to $1\frac{7}{8}$" "	$7\frac{5}{8}$	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{3}{16}$	$\frac{5}{32}$	$2\frac{3}{4}$	$\frac{1}{8}$	$\frac{3}{32}$	$3\frac{3}{4}$	$2\frac{3}{4}$	$\frac{7}{32}$	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{1}{32}$	$5\frac{5}{8}$	$\frac{1}{2}$	$1\frac{3}{4}$	6
$1\frac{15}{16}$" to $2\frac{1}{4}$" "	$8\frac{3}{4}$	$1\frac{7}{16}$	$\frac{11}{16}$	$\frac{7}{32}$	$\frac{3}{16}$	$3\frac{1}{4}$	$\frac{5}{32}$	$\frac{1}{8}$	$4\frac{1}{4}$	$3\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{16}$	$6\frac{1}{2}$	$\frac{5}{8}$	2	6

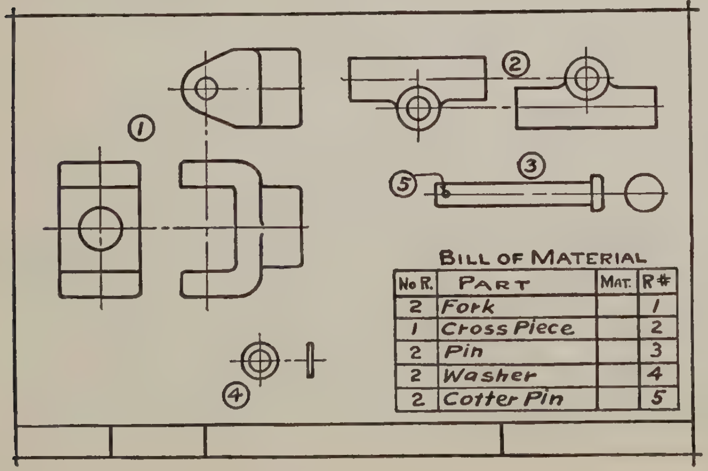
FLANGE COUPLING

SPECIFICATION—PROBLEM 11

Make an assembly working drawing of a Universal Coupling as shown on the lay-out sheet, page 61, for a 1½ inch diameter shaft. Show all dimensions and indicate the kinds of materials with notes. Scale 12 inches equals 1 foot.

This form of coupling is used for connecting two shafts, the axis of which are not in line with each other but which merely intersect at a point. There are many different designs in vogue which are used in automobile drives and on various machine tools such as milling machines and multiple spindle drill presses. The form in this drawing consists of two similar forked hubs, one on the driven shaft and one on the driving shaft, which engage a single cross shaped block by means of two pins passing thru holes in the block at right angles to each other. The pins are held in place with a washer and a split pin. The proportions given are suitable for forgings or steel castings used with hardened tool steel pins. This type of coupling will not work well if the angle between the axis of the two shafts to be connected is more than 45 degrees.

A good problem is to draw the coupling in detail using the size for a 1 inch diameter shaft and the lay-out as given on this page.



BILL OF MATERIAL

No R.	PART	MAT.	R #
2	Fork		1
1	Cross Piece		2
2	Pin		3
2	Washer		4
2	Cotter Pin		5

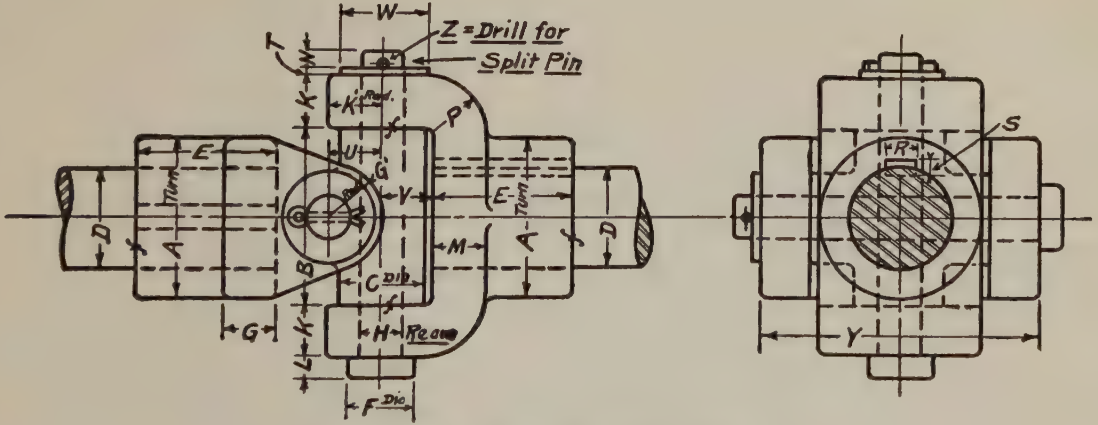


TABLE OF PROPORTIONS

D = Dia. of shaft
A = 1.8D
B = 2D
C = D
E = 1.6D
F = .75D

G = .6D
H = .5D
K = .6D
L = .25D
M = G = K
N = .25D

P = K
R = Standard Size
S = " " "
T = .075D (approx)
U = K
V = K

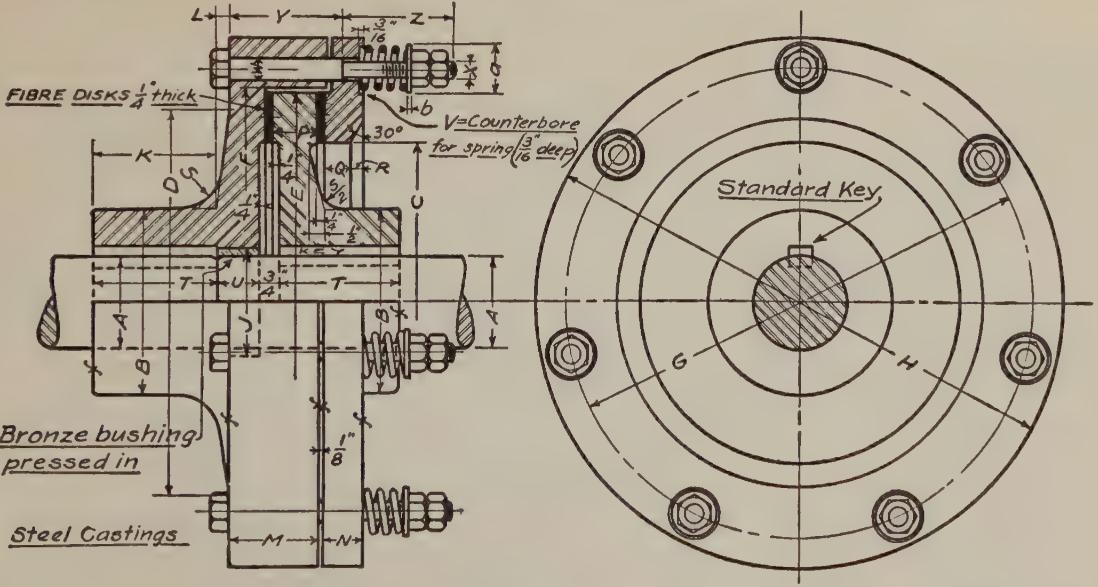
W = C = D
Y = B + 2K
Z = .125D
K' = K
G' = K

UNIVERSAL COUPLING

SPECIFICATION—PROBLEM 12

Make an assembly working drawing of a five horse-power Slip Coupling for a 3-inch diameter shaft, with views arranged as shown on the lay-out sheet, page 63. Scale 6 inches equals 1 foot. Draw the view which is sectioned and as much of the circular view as the sheet will allow. One of the other sizes given in the table may be used and drawn to a suitable scale. The drawing on the layout sheet is of a seven horse-power coupling for 3½-inch diameter shaft, the sizes of which are not given in the table. Omit the letters and table and indicate all dimensions and notes necessary for a complete working drawing from which the parts are to be made. All such dimensions as, for example, the pitch of the spring coils which is given in the table, must be placed on the drawing.

In many installations it is desirable to use some form of coupling that will slip when the load is excessive and thus protect motors, gears, etc., against injury when there is an overload or when power is applied suddenly. For this purpose some form of slip coupling is used. The coupling in the drawing represents the design used by the Illinois Steel Co. on the drives of rolling mill machinery and is really a type of single-disc friction coupling. A flanged hub is keyed to the driving shaft and has bolted to its rim a plate or flat ring. Between this flanged hub and the ring and separated from them by flat fibre rings or discs, is the flange of the hub which is keyed to the driven shaft. The bolts connecting the plate to the driving hub are provided with springs which create a pressure on both faces of the flange of the driven hub. The pressure may be varied by adjusting the nuts of the coupling bolts. The driven shaft extends through the driven hub and is supported at its end in a bronze lined bearing in the driving hub. This assists in keeping the hubs in alignment and in preventing chattering when slipping occurs.



ILLINOIS STEEL CO. TABLE OF SIZES. —

H.P. at 100 R.P.M.	Max. Bore	DIAMETERS. —																			BOLTS.					Washers		SPRINGS.				
	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S	T	U	V	No Req'd.	W	X	Y	Z	a	b	Na	OUTS. DIAM.	LENGTH	DIAM. WIRE	PITCH OF COILS
5	3	6	11	12 1/2	13 3/4	14	15 1/2	18 1/2	3 5/8	3 7/8	1/2	3 1/4	1 1/4	1 1/2	1	3/8	1 1/4	3 3/4	1 5/8	2 1/4	6	13/16	3/4	4	3 7/8	2	3/16	6	2	1 3/4	1/4	1/2
50	5	10	16	23 1/2	24 3/4	25	27	30	6	6 3/4	3/4	4	1 3/4	2	1 1/4	5/8	2	6 1/4	2 1/2	2 1/4	10	1 3/16	1 1/8	5 1/4	4 5/8	2	3/16	10	2	1 3/4	3/8	9/16
100	6	12	19	29 1/2	30 3/4	31	33	36 1/2	7	7 1/2	3/4	5	2	2 1/2	1 1/2	5/8	2	7 1/2	2 1/2	2 3/4	12	1 3/16	1 1/8	6 1/2	5 3/8	2 1/2	3/16	12	2 1/4	2 1/2	7/16	5/8

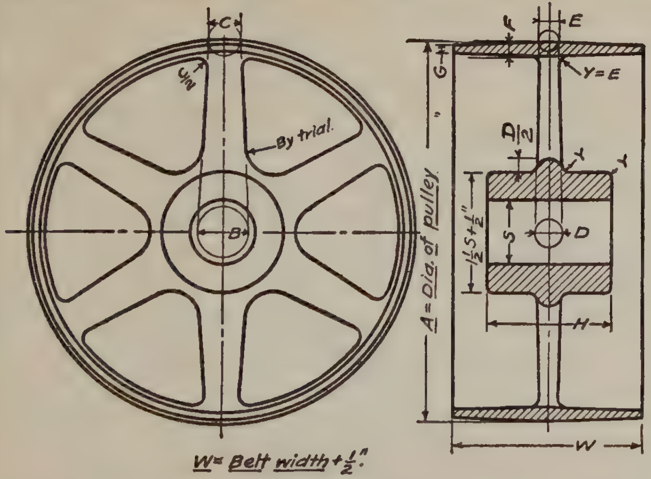
SLIP COUPLING.

SHAFTING AND PULLEYS

Shafting.—Shafting is made from various grades of hot rolled and cold rolled steel. Turned shafting is made from hot rolled bar stock which is rough and must be turned in a lathe and polished accurately to size. Cold rolled or drawn shafting has a comparatively smooth surface, is fairly true and uniform in size and can be used for many purposes without machining. It is produced by treating hot rolled bar stock with an acid so as to clean the outer surface, and then drawing it through special dies. In the drawing process the surface acquires a polished appearance and becomes somewhat harder. Cold rolled or drawn steel shafting may be obtained in sizes varying by one-sixteenth inch increments. Rectangular and hexagonal bars, and sheet steel are also made by the cold drawing or cold rolling process.

Pulleys.—Pulleys for belt drives are made from a variety of materials including cast-iron, wood, pressed steel, and compressed paper. Cast-iron pulleys are the most common and are generally used with flat belts made of leather or cotton and rubber. Since a belt in operation tends to run to the highest part of a pulley, the faces of pulleys are turned "crowned" or high at the center. Crowning assists in keeping the belt near the center of the pulley. Small pulleys are sometimes provided with flanges to prevent the belt from slipping off. Pulleys are secured to shafts by means of set-screws and keys. Some pulleys are made in two parts which are clamped to the shaft with bolts. They are known as split pulleys. On page 65 are given proportions and dimensions for cast-iron pulleys.

DIMENSIONS OF CAST IRON PULLEYS



W = Belt width + $\frac{1}{2}''$.

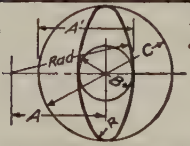
FORMULAS FOR ARM SIZES.

A = Diameter of pulley in inches.
B = Width of arms at center of pulley.
C = " " " " rim " " .
D = Thickness of arms at center of pulley.
E = " " " " rim " "

$$B = .0625A + .5''$$
$$C = .04A + .3125''$$
$$D = .025A + .2''$$
$$E = .016A + .125''$$

Change decimal results to nearest sixteenths.

METHOD OF DRAWING ARM SECTION.



Dia. of C = Width of Arm.
Dia. of B = Thickness " "
A = A'
R = By trial
Rad = A + $\frac{B}{2}$

DIMENSIONS OF ARMS. Based on formulas above.

A	B	C	D	E	A	B	C	D	E
6	$\frac{7}{8}$	$\frac{9}{16}$	$\frac{5}{16}$	$\frac{1}{4}$	11	$1\frac{3}{16}$	$\frac{3}{4}$	$\frac{7}{16}$	$\frac{5}{16}$
7	$\frac{15}{16}$	$\frac{9}{16}$	$\frac{3}{8}$	$\frac{1}{4}$	12	$1\frac{1}{4}$	$\frac{13}{16}$	$\frac{1}{2}$	$\frac{5}{16}$
8	1	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{1}{4}$	13	$1\frac{5}{16}$	$\frac{13}{16}$	$\frac{1}{2}$	$\frac{5}{16}$
9	$1\frac{1}{16}$	$\frac{5}{8}$	$\frac{7}{16}$	$\frac{1}{4}$	14	$1\frac{3}{8}$	$\frac{7}{8}$	$\frac{1}{2}$	$\frac{3}{8}$
10	$1\frac{1}{8}$	$\frac{11}{16}$	$\frac{7}{16}$	$\frac{1}{4}$	15	$1\frac{7}{16}$	$\frac{7}{8}$	$\frac{9}{16}$	$\frac{3}{8}$

RIM SIZES.

A	F	G
6 to 16	$\frac{1}{4}$	$\frac{1}{8}$
17 to 30	$\frac{5}{16}$	$\frac{3}{16}$
32 to 46	$\frac{3}{8}$	$\frac{1}{4}$
48 to 52	$\frac{7}{16}$	$\frac{5}{16}$
54 to 60	$\frac{1}{2}$	$\frac{3}{8}$

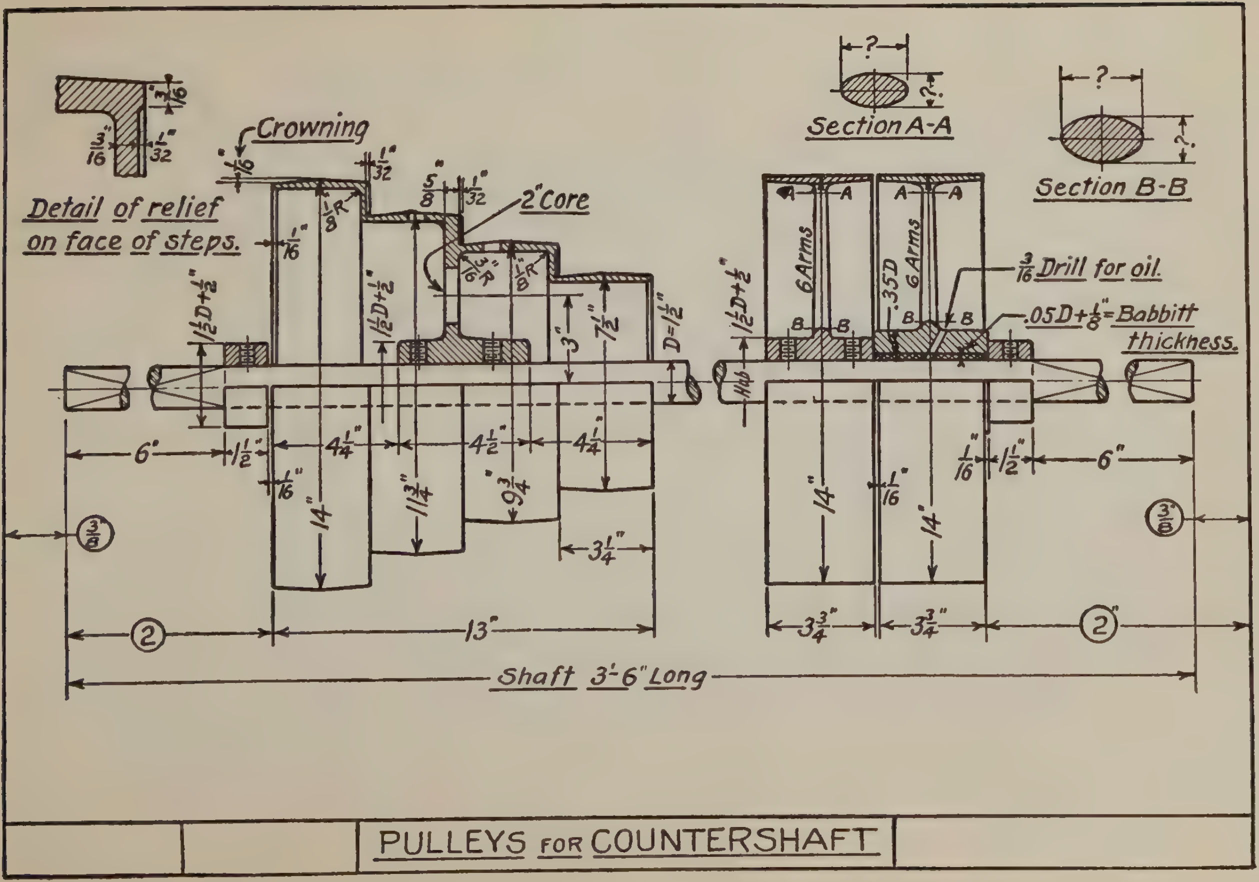
MINIMUM LENGTH OF HUB.

Shaft Dia.	H	Shaft Dia.	H
1 to $1\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{5}{16}$ to $2\frac{1}{2}$	5
$1\frac{5}{16}$ to $1\frac{1}{2}$	3	$2\frac{9}{16}$ to $2\frac{3}{4}$	$5\frac{1}{2}$
$1\frac{9}{16}$ to $1\frac{3}{4}$	$3\frac{1}{2}$	$2\frac{13}{16}$ to 3	6
$1\frac{13}{16}$ to 2	4	$3\frac{1}{8}$ to $3\frac{1}{2}$	7
$2\frac{1}{16}$ to $2\frac{1}{4}$	$4\frac{1}{2}$	$3\frac{5}{8}$ to 4	8

SPECIFICATION—PROBLEM 13

Make an assembly working drawing of the Pulleys for Countershaft as shown on the lay-out sheet, page 67. Scale 6 inches equals 1 foot. Show all the dimensions, notes, finish marks, etc., necessary to make and assemble the pulleys, collars, and shaft. The minimum thickness of the metal in the cone pulley is $\frac{3}{16}$ inch. The cone pulley is turned outside, and rough-bored inside. It has six cored holes 2 inches diameter in the web. The steps are all the same face or width and they are all to be crowned. The tight and loose pulleys are to be designed with the aid of the table of pulley dimensions on page 65. Both the light and loose pulleys are turned with a straight face, no crowning. In drilling holes for the set-screws in the hub, it is necessary to drill through the rim. The isolated sections of the arms should be drawn full size.

A countershaft is supported in bearings and is used between the main power shaft in a shop, generally known as the line shaft, and a machine in which a variable speed is desired. It consists of a shaft upon which is mounted a cone pulley of various diameters or "steps," a tight pulley, and a loose pulley. The driving belt from the line shaft to the counter-shaft can be shifted to connect with either the tight or the loose pulley. A belt on the cone pulley connects with a similar cone pulley on the machine which is so placed that the small step on the machine cone pulley is in line with the large step on the counter-shaft cone pulley. By means of this arrangement the machine may be stopped or started at will and may be given as many different speeds as there are steps in the cone pulley. When a belt runs on one step, one edge of the belt is very apt to rub against the face of the next larger step. To prevent excessive friction the steps are counter-faced or "relieved."


Detail of relief on face of steps.
3/16"
3/16
1/32"
Crowning
1/16"
1/32"
1/8"R
5/8"
1/32"
2" Core
1/16"
3/16"R
1/8"R
1 1/2D+1/2"
1 1/2D+1/2"
3"
7 1/2"
D=1 1/2"
6"
1 1/2"
4 1/4"
4 1/2"
4 1/4"
1/16"
14"
11 3/4"
9 3/4"
3 1/4"
3/8
2
13"
Section A-A
Section B-B
?
A
B
6 Arms
.35D
3/16 Drill for oil.
.05D+1/8" = Babbitt thickness.
Hub
1 1/2D+1/2"
14"
1/16"
14"
1/16"
1 1/2"
6"
3/8"
3 3/4"
3 3/4"
2"
Shaft 3'-6" Long
PULLEYS FOR COUNTERSHAFT

BEARINGS

There are three types of bearings in common use in machinery, namely: (1) rectilinear bearings; (2) journal bearings; (3) thrust bearings. All of these may be either sliding bearings or rolling bearings according to the manner in which the bearing surfaces are in contact with each other. Sliding bearings have a sliding contact and are commonly termed plain bearings. Ball bearings and roller bearings have a rolling contact. In a rectilinear bearing the motion is reciprocating and parallel to the elements of the bearing surfaces. Engine crossheads and the ways of planers, shapers, and lathes, are classed as rectilinear bearings. The journal bearing consists of a cylindrical shaft or spindle which rotates within another machine part or which supports another part that rotates upon it. The shaft or cylindrical part is called the journal and the part which encloses and supports the journal is called the box or less specifically the bearing. In a journal bearing, also termed a radial bearing, the load is at right angles to the axis. A thrust bearing is a rotary bearing in which the load acts parallel to the axis.

Bearing Metals for Plain Bearings.—Shafts, spindles, and other journals are most commonly made of steel. In well designed machinery the boxes or bearings which carry the journals are lined with a material that will offer the least frictional resistance and wear, and enough compressive resistance to carry the necessary load without becoming distorted. Bearing metals for steel shafts are usually composed of alloys of copper, lead, tin, antimony, and zinc, and are known as babbitt metal, white metal, bronze, and various trade names. Babbitt metal, of which there are many varieties, is used more extensively than any other bearing material in plain bearings. See table on page 69. It can be melted easily in a common iron ladle and poured into the box while the journal is held in position. The box or shell which is usually made of cast-iron must be provided with some form of anchor to prevent rotation of the babbitt lining. The anchors usually consist of dovetail grooves, or cored or drilled holes into which the babbitt may flow when the bearing liner is cast.

Adjustments for Wear.—In most bearings provision is made for taking up wear. The adjustments to compensate for wear may be made in various ways; but the most common method is by the use of split bearings the parts of which are bolted together. When wear occurs, the parts of the bearing, generally two in number, are brought closer to each other by removing some of the metal or paper shims between them and tightening the bolts, thereby taking up the play. In the simplest form of bearing, the hole in the part which forms the support for the shaft is lined with a bushing of some bearing metal. When the bushing becomes worn it can be replaced.

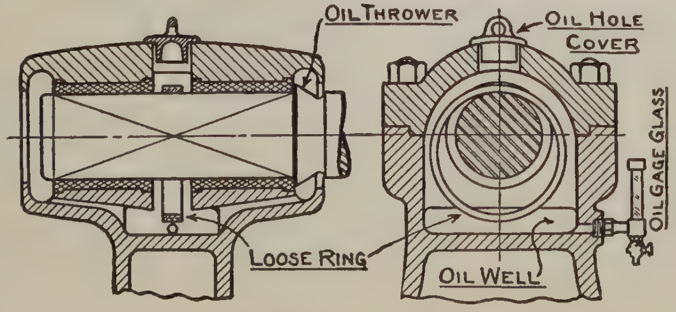
BABBITT METAL COMPOSITIONS

Class of Service Adapted for	Composition of Metal			
	Tin	Antimony	Copper	Lead
High pressure and fast speed	86	12	2	....
Medium pressure and fast speed	30	20	....	50
Medium pressure and medium speed	15	25	....	60
Low pressure and medium speed	8	20	....	72
For line shafting, etc.	....	10	....	90
*S. A. E. Babbitt Metal for connecting rod linings of motor bearings	84	9	7	....

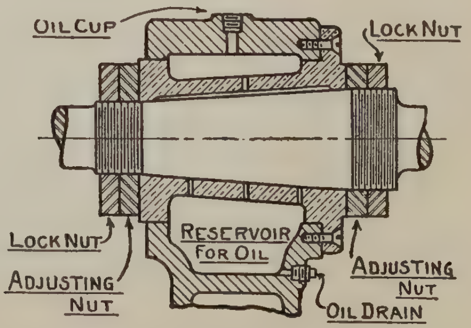
*S. A. E. Bronze for use against hardened steel shafts has the following composition: Copper 80%, Tin 10%, Lead 10%, Phosphorus .05% to .025%.

SPECIFICATION—PROBLEM 14

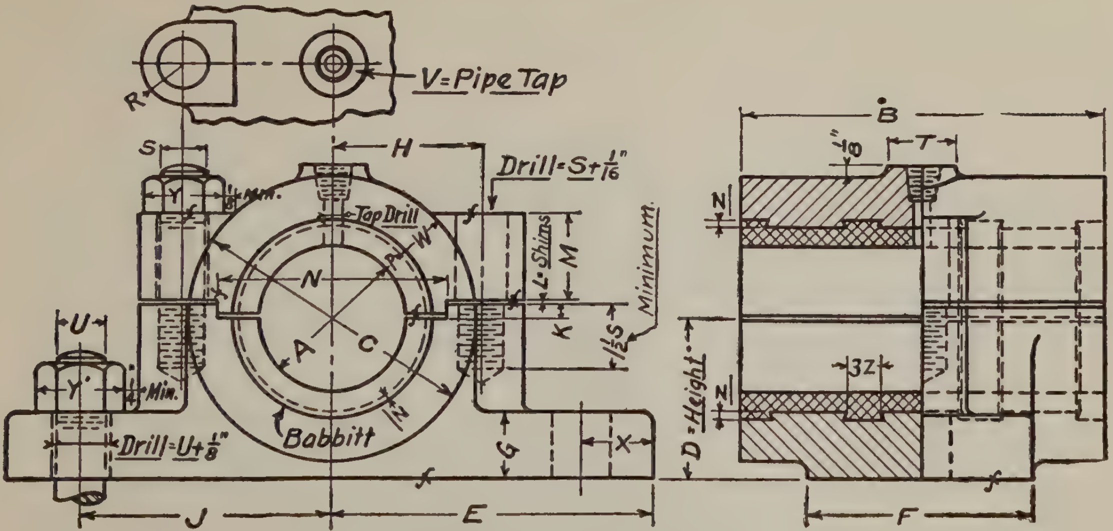
Make a working drawing of a Split Babbitted Bearing for a 1¾ inch diameter shaft showing the front and side views as shown on the lay-out sheet, page 71, and the top view completed. Show the studs and nuts in the left side of the front view only. Omit all dotted lines in the top view except the two indicating the hole for the shaft. Omit the letters and table of proportions and indicate all dimensions and notes necessary for a complete working drawing from which the parts can be made. Scale 12 inches equals 1 foot. Any other size included in the table may be used and drawn to a suitable scale. The angle of the dovetail anchor grooves, which are cored, can be made 60 degrees. Oil cups, grease cups, and oiling fittings and devices are furnished with pipe threads; hence the oil hole in the bearing is tapped to receive pipe threads. Use ⅛ inch for the 1¾-inch diameter bearing. Plain bearings are made in a great variety of designs, to suit the conditions of service under which they are to operate. Provision must always be made for lubrication so as to reduce frictional resistance and wear.



A RING-OILED BEARING



A TAPER ADJUSTMENT BEARING



FOR SHAFTS 1" TO 4" DIAM.

$A =$ diameter of shaft
$B = 2A$ to $2.5A$
$C = 1.8A + \frac{1}{4}'' = A + 2P + 2W$
$D = .5C + \frac{1}{4}''$ (minimum)
$E = J + X$
$F = 1.5A$

$G = .33A$ (min. $= .25A + \frac{5}{16}''$)
$H = .95A + \frac{1}{8}''$
$J = H + R + \frac{1}{4}'' + .5Y'$
$K = .08A + \frac{1}{4}''$
$L = .042A$ (for shims)
$M =$ to suit H and Y

$N = 1.45A + \frac{1}{4}''$
$P = .05A + \frac{1}{8}''$
$R = .29A$
$S = .25A$ (use U.S.S. size)
$T = 1.5 \times$ Outside dia. of $V + \frac{1}{4}''$
$U = .33A$ (use U.S.S. size)

$V = \frac{1}{8}''$ to $\frac{3}{8}''$ Pipe Tap
$W = .35A$
$X = 1.3U.$
$Y =$ Std. Hex. nut across corners
$Y' =$ " " " " "
$Z = \frac{1}{8}''$ to $\frac{1}{4}''$

SPLIT BABBITTED BEARING

THE SPUR GEAR

A spur gear is a wheel that is provided with small projections called teeth on its circumference for the purpose of transmitting positive motion to another gear or similarly toothed machine part. Spur gears are very useful in machine construction, as by the use of them power can be carried from one part of a machine to another without loss of motion and at any desired speed ratio.

One of the most common uses of spur gears is to connect two parallel shafts so that when one is turned it will cause the other to turn in the opposite direction. This can best be illustrated by two cylinders mounted on shafts as in Figure 1 so that there is frictional contact between them. When cylinder *A* is turned once around, cylinder *B* makes one revolution also, providing, of course, they are of the same size and there is no slipping between the two cylinders. The speed or velocity ratio here would be 1 to 1. If one cylinder were exactly twice as large as the other, the smaller would make two turns while the larger makes one. The velocity ratio would then be 2 to 1. This relative difference in velocity is regulated by the relative difference in the size of the respective cylinders and is a very useful principle in mechanics. No dependence, however, can be placed on frictional contact for positive driving as a little overload on the driving cylinder would cause a loss of motion thru slipping. By cutting small grooves, "dedenda" on the periphery of the cylinders and adding short projections, "addenda," between the grooves as in Figure 2, teeth which engage each other are formed. Slipping is now overcome and the cylinders have become gears thru which positiveness of motion is obtained.

There is, however, another consideration in gearing which is smoothness of motion. Unless the correct shape is given to the teeth, the gears will move with a jerky irregular motion. Hence, a very important problem is that of making the teeth of such shape that they will transmit motion smoothly. In machine shop practice, that problem has been solved by using definite proportions and curves for the tooth shape; and it is to a study of the modern gear tooth that we will now turn.

Gear Teeth.—The teeth on gears are cast in a mold in the foundry or cut in a gear cutting machine in the machine shop. Gears made of iron or steel with cast teeth are inaccurate, noisy, and suitable only for rough construction. Gears with cut teeth can be made very accurate and are used

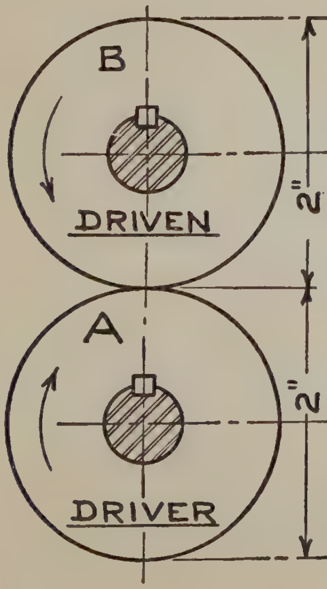


FIG. 1

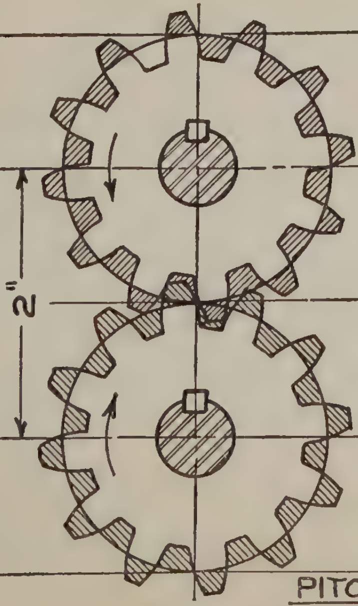


FIG. 2

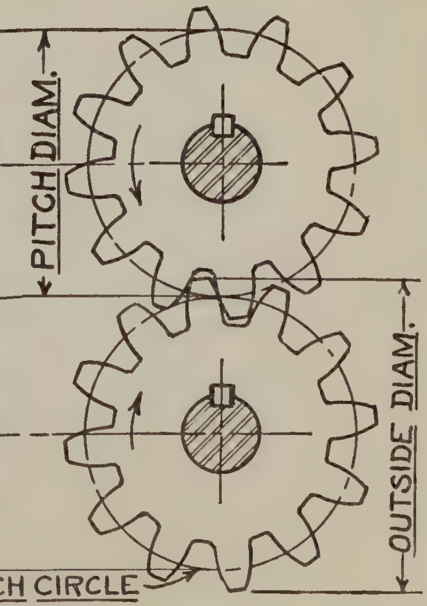


FIG. 3

in all machines where smooth action is desired. The cylinders or gear blanks, as they are called, are turned accurately to the proper "outside diameter" (Figure 3, page 73) on a lathe, after which the teeth are evenly spaced and cut in one of several types of gear cutting machines employing cutters that give the true shape and size to all teeth.

Tooth Proportions.—There are many systems of tooth proportions for cut gears but only two are in common use, namely, The Brown & Sharpe 14½-degree involute tooth system and the Fellows 20-degree involute stub tooth system. Both of these are laid out with the idea of interchanging all gears in the system. They were developed, respectively, by the Brown & Sharpe Manufacturing Co. of Providence, Rhode Island, manufacturers of gears, gear cutting machinery, and machinists' tools, and the Fellows Gear Shaper Co. of Springfield, Vermont, manufacturers of gears and gear cutting machinery. For general purposes, gears with Brown & Sharpe tooth proportions are used. The Fellows Stub Tooth proportions are commonly used for gears in automobile construction. The Brown & Sharpe system will be discussed first.

Brown & Sharpe Tooth System.—The proportions and dimensions of Brown & Sharpe gear teeth are generally based on the diameter of the original friction cylinder, Figure 1, page 73. This cylinder is called the *"pitch cylinder"* and the line representing it is called the *"pitch circle"* or *"pitch line."* The pitch circle exists geometrically in all gears. The teeth lie partly within and partly without it; and in two mating gears these imaginary circles are tangent. The diameter of the pitch circle is called the *"pitch diameter."* See Figure 3. It is the basis for most gear tooth calculations.

In theory, gear teeth can be made an indefinite number of sizes ranging from very small to very large teeth. In practice there is a limited number of definite sizes. The sizes are standardized and, instead of being known by their actual dimensions in inches, are most commonly designated by the number of teeth for each inch of the pitch diameter. This proportion is called the "diametral pitch." It is not a dimension on the gear tooth but is simply a ratio which determines the size of the tooth. Hence the term diametral pitch refers to the *size of the tooth* and is the *number of teeth for each inch of the pitch diameter.* To illustrate: A gear having a pitch diameter of 6 inches and teeth of 8 diametral pitch, must have 48 teeth. If the teeth were larger, let us say 5 diametral pitch and the pitch diameter were 6 inches, the gear would have 30 teeth. The pitch diameter multiplied by the diametral pitch will always equal the number of teeth; and the number of teeth divided by the diametral pitch will give the pitch diameter. Examples: Gear, 48 teeth 8 diametral pitch = 6″ pitch diameter; gear, 30 teeth 6″ pitch diameter = 5 diametral pitch.

Gear teeth sizes are sometimes designated by "circular pitch" which is the distance between the centers of two teeth measured along the pitch circle. Diametral pitch multiplied by circular pitch equals 3.1416; hence diametral pitch equals 3.1416 divided by circular pitch; circular pitch equals 3.1416 divided by diametral pitch.

On heavy mill gearing where the teeth are very large, the circular pitch system is often used. Another important use of the circular pitch system is in replacements for old drives where the original gearing was cast-tooth gearing. On most old cast-tooth gears the circular pitch was used. The circular pitch is used today for cut gears which replace the old cast-tooth gears. When the word pitch alone is used, diametral pitch is understood.

Fig. 4, page 76, shows Brown & Sharpe gear teeth with the names and proportions of the parts. The groove between two teeth is called a "space." In theory, the depth of the space equals the "addendum" plus the "dedendum," but in order to allow the teeth of mating gears to pass the bottom of the space without friction, and to provide room for a good fillet at the base of the tooth, the space is made deeper by an amount which is called "clearance." The outside diameter is found by adding two times the addendum to the pitch diameter. (Some gear men refer to the entire distance from the pitch circle to the root circle as the dedendum. In this discussion the clearance will be considered separately.)

Fellows Stub Tooth System.—The Fellows stub tooth, as the name suggests, has a shortened addendum and dedendum. It is used largely in automobile construction and where a very strong tooth is desired. In this system the sizes of teeth are designated by two numbers expressed in the form of a fraction as follows: 4/5, 5/7, 6/8, 7/9, 8/10, 9/11, 10/12, and 12/14. The numerator is used for calculating the pitch diameter and the number of teeth, whereas the denominator is used for calculating the addendum and dedendum. In the case of the 6/8 pitch, for in-

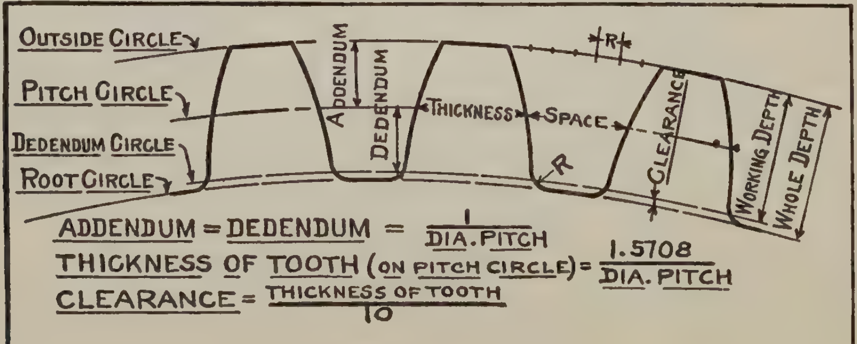
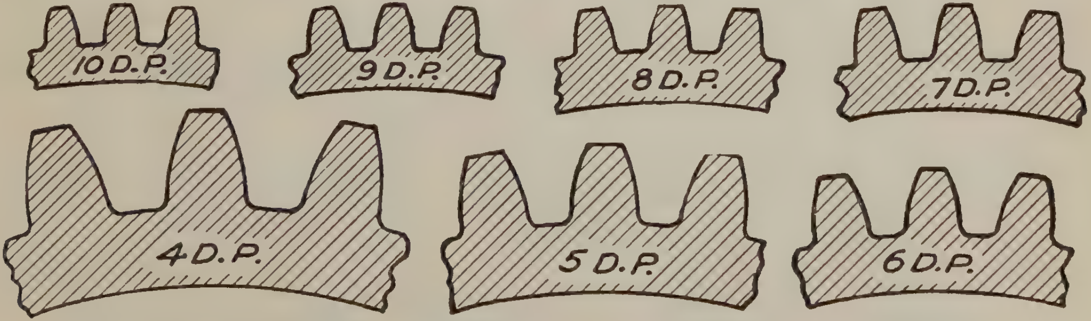

OUTSIDE CIRCLE
PITCH CIRCLE
DEDENDUM CIRCLE
ROOT CIRCLE
ADDENDUM
DEDENDUM
THICKNESS
SPACE
R
R
CLEARANCE
WORKING DEPTH
WHOLE DEPTH
ADDENDUM = DEDENDUM = 1 / DIA. PITCH
THICKNESS OF TOOTH (ON PITCH CIRCLE) = 1.5708 / DIA. PITCH
CLEARANCE = THICKNESS OF TOOTH / 10

FIG. 4

stance, the numerator of the fraction signifies that the gear is of 6 diametral pitch, in so far as its pitch diameter is concerned, while the denominator signifies that the addendum is ⅛ inch high. A 24-tooth gear of 6/8 pitch would have a pitch diameter of 4 inches; and an addendum of ⅛ inch. The outside diameter would be 4¼ inches. The clearance is greater than in the Brown & Sharpe system and equals one-fourth of the addendum.



COMPARATIVE SIZES OF GEAR TEETH.

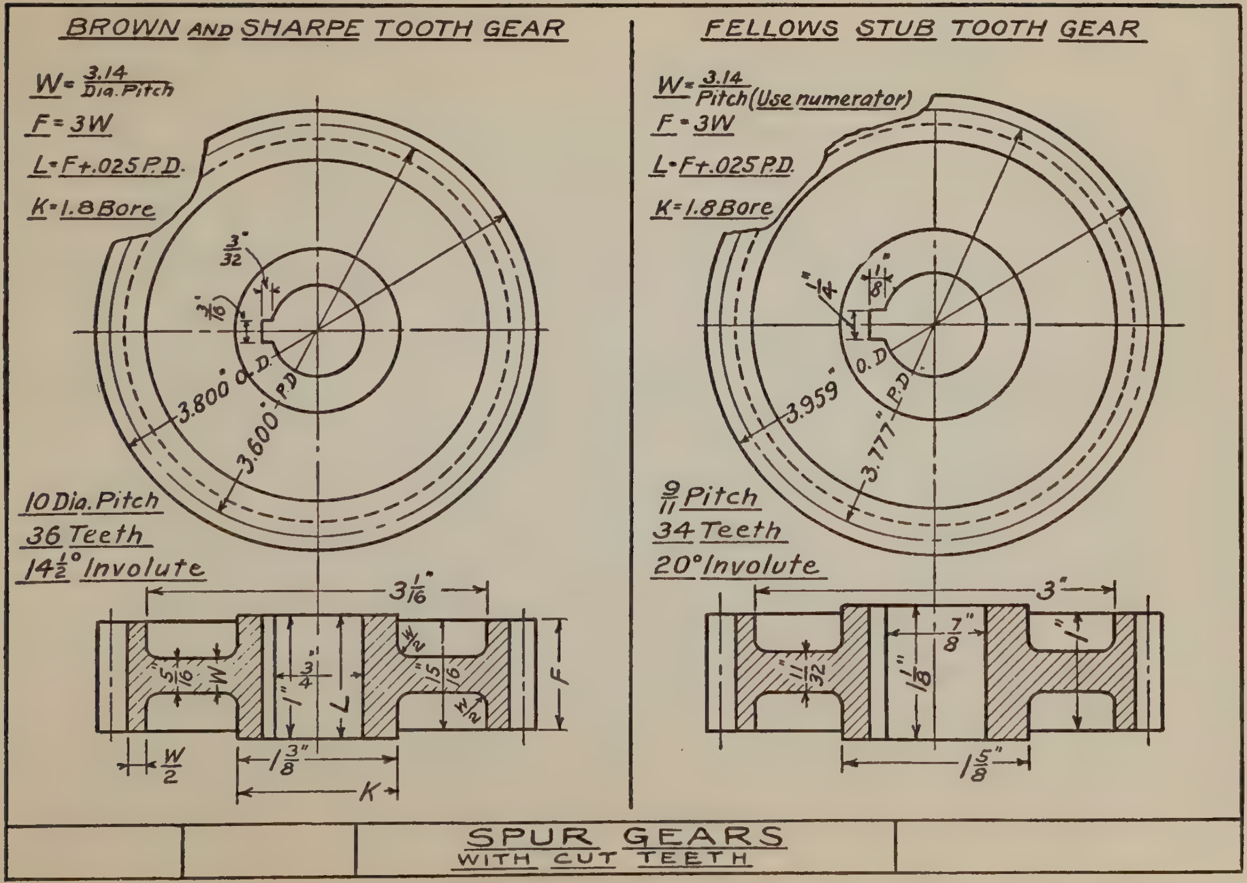
FIG. 5

SPECIFICATION—PROBLEM 15

Make a complete working drawing of a Brown & Sharpe tooth gear and a Fellows stub tooth gear as shown on the lay-out sheet, page 79. Scale 12 inches equals 1 foot. Show all dimensions and notes as suggested but omit the formulae and the letters pertaining to the formulae. For the Brown & Sharpe gear use one of the following sizes: 46 Teeth—8 Diametral Pitch; 28 T.—5 D. P.; 40 T.—7 D. P.; 34 T.—6 D. P.; 48 T.—9 D. P.; 54 T—10 D. P. For the Fellows gear use one of the following sizes: 28 Teeth—5/7 Pitch; 30 T.—6/8 P.; 22 T.—4/5 P.; 35 T.—7/9 P.; 42 T.—8/10 P.; 50 T.—9/11 P. The bore is 1⅛ inches in all cases. The tooth outlines are not to be drawn in this drawing.

In drawing the circles representing the teeth, use the following procedure: (1) Calculate the pitch diameter and draw the pitch circle (light center line). (2) Calculate and lay off the addendum, the dedendum, and the clearance on the vertical center line. (3) Draw the outside circle (full object line) and the clearance, or root circle (dotted object line).

Drawings for Cut Gears.—In drawings for cut gears, the outlines of the teeth need not be shown. It is sometimes necessary to draw one or two teeth so as to show the relative position of a tooth or a space, and the keyseat or some other part of the gear; but it is unnecessary to take pains in drawing the curvature of the gear teeth, because the exact form of the teeth is controlled by the gear cutting process. The following information and dimensions, however, are necessary for sizing the blank and cutting the teeth and should appear on the drawing: (1) Number of teeth; (2) Kind of teeth (Brown & Sharpe 14½-degree involute tooth, or Fellows 20-degree involute stub tooth); (3) Diametral pitch, or circular pitch; (4) Outside diameter, in decimals to three places; (5) Pitch diameter in decimals to three places. When drawing includes a pair of gears in mesh, the distance from the center to center of gears should also be given.


BROWN AND SHARPE TOOTH GEAR
W = 3.14 / Dia. Pitch
F = 3W
L = F + .025 P.D.
K = 1.8 Bore
3/32"
3/16"
3.800" O.D.
3.600" P.D.
10 Dia. Pitch
36 Teeth
14½° Involute
3 1/16"
5/16"
W
3/4"
1"
L
15/16"
W/2
F
W/2
1 3/8"
K
FELLOWS STUB TOOTH GEAR
W = 3.14 / Pitch (Use numerator)
F = 3W
L = F + .025 P.D.
K = 1.8 Bore
1/4"
1/8"
3.959" O.D.
3.777" P.D.
9/11 Pitch
34 Teeth
20° Involute
3"
7/8"
11/32"
1 1/8"
1"
1 5/8"
SPUR GEARS
WITH CUT TEETH

Gear Tooth Curves.—There is a number of curves that might be used for tooth outlines, but only two have ever been used to any great extent. They are known as the "involute curve," and the "cycloid curve." Along with the development of machines for cutting gear teeth rapidly, the cycloid form of tooth was dropped, and today we find that the involute is the only curve for gear teeth in common use. Among the reasons for the adoption of the involute curve in preference to all other forms is the fact that it lends itself more readily to various methods of cutting, and that it is capable of transmitting uniform motion at varying center distances. The cycloid form will transmit uniform motion only on theoretically correct center distances.

Theory of Gear Tooth Outlines (Involute).—The outline of the engaging surface of a gear tooth is a curve that fulfills a certain condition or law. To assist in explaining this law, reference is made to Fig. 6, which shows the tooth outlines of a portion of two gears in mesh. It is assumed that gear *A* is driving gear *B* in the direction shown by the arrow. The pitch circles of the gears are tangent to each other at point *M* on the line of centers. This point is sometimes called the "pitch point." Teeth *X* and *Y* will be used in this explanation altho any other pair that is in action would illustrate the principle. Tooth *X* is in contact with tooth *Y* at point *C*. Line *D-E* is drawn tangent to the tooth curves at this contact point *C*. Line *F-G*, which is drawn perpendicular to line *D-E* at point *C*, is normal to the tooth curves, and is called the "line of action." The principle involved in constructing smooth-acting gear tooth curves is that the line of action *F-G* must pass thru the pitch point *M* for every position in which the two teeth are in contact as the gears are rotated. Therefore, if gears are to run smoothly, the tooth curves must be so shaped that contact takes place only on the line of action. The line of action is also known as the "line of pressure," and the angle that it makes with line *H-K*, drawn tangent to the pitch circles at point *M*, is called the "angle of action" or "pressure angle." If the pressure angle is increased, the tooth curves become more sharp; and if it is decreased, the curves more nearly approach a straight line. If the pressure angle is very great, there is apt to be a slight tendency on the part of the gears to press apart the shafts on which they are mounted.

Standard Pressure Angles.—The Brown & Sharpe system and the Fellows Stub Tooth system both employ the involute curve in the outline of the teeth, but they have different pressure angles. The Brown & Sharpe involute system, which is the older, has a pressure angle of 14½ degrees.

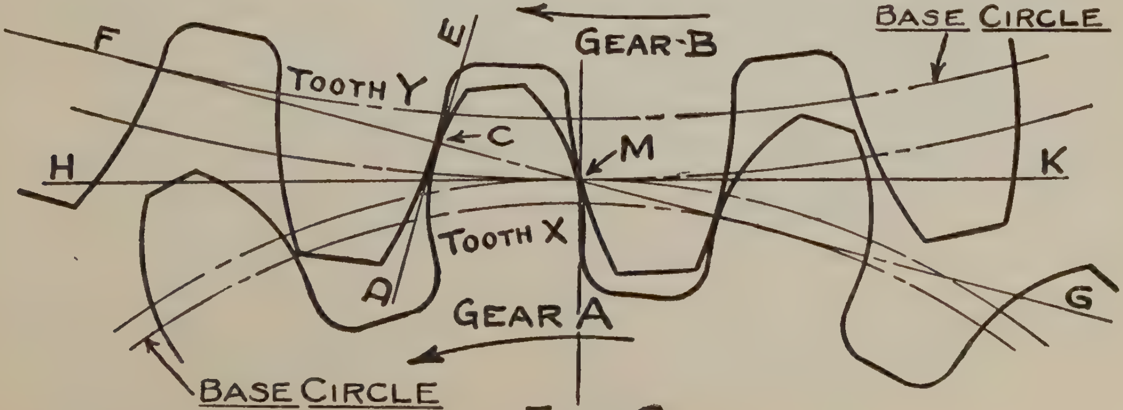


FIG. 6

Gears that have their teeth cut to this form are sometimes called "standard tooth gears" or "14½ degree gears." The Fellows Stub Tooth, developed by the Fellows Gear Shaper Co. in 1899, is now almost universally adopted for gears used in automobiles. It has a pressure angle of 20 degrees and, as explained before, a shortened addendum. Cast gear teeth are generally made with a pressure angle of 15 degrees.

Base Circle.—A circle which is drawn from the center of the gear, tangent to the line of pressure, is known as the "base circle." The involute-curved part of the teeth extends outward only from the base circle as the teeth do not come in contact with each other inside of this circle. The base circle exists geometrically in all gears and is the circle from which the involute tooth curves are developed, Fig. 6, page 81. It is always smaller than the pitch circle and its relative diameter is dependent on the pressure angle as it is drawn tangent to the line of action. The diameter of the base circle can be found by multiplying the pitch diameter by the cosine of the pressure angle; cosine 14½ degrees equals 0.968; 20 degrees equals 0.939; 15 degrees equals 0.965.

Generating the Involute Curve.—The involute curve may be generated in the following manner, which is illustrated in Fig. 7: Cut a circle out of a thick card and tack it to the drawing board. Attach a short thread to the edge of the card by means of a pin. Form a loop at the loose end of the thread. Wind the thread about the circular edge of the card, stick a pencil in the loop, then unwind the thread with the pencil point in the loop and the thread stretched taught. If the pencil point is kept pressed to the board as the thread is being unwound, it will describe an involute curve on the board. The circle from which the curve was generated represents the base circle.

To Draw the Involute Curve.—The involute curve may be drawn by using a series of connected arcs as shown in Fig. 8. Lay off points *B, C, D, E,* etc. on the periphery of the base circle and draw lines *B-B′*, *C-C′*, etc., tangent to the circle at these points. From point *B*, with a radius equal to the distance *B-A measured on the circle,* strike an arc as indicated. From point *C*, with a radius equal to *C-A measured on the circle,* strike a similar arc. In like manner draw arcs from points *D, E,* etc. These arcs when joined as shown, will form a close approximation to the involute curve.

Drawings for Cast Gears.—In drawings for cast gears it is sometimes necessary to show the exact shape and size of a few teeth. Various methods which are known as "ondontographs" have been devised for drawing approximate gear tooth outlines. Of these probably the most commonly used is that by Geo. B. Grant, author of *A Treatise on Gear Wheels.* With Grant's method the involute curved part of the outlines of the teeth may be drawn accurately by means of circular arcs

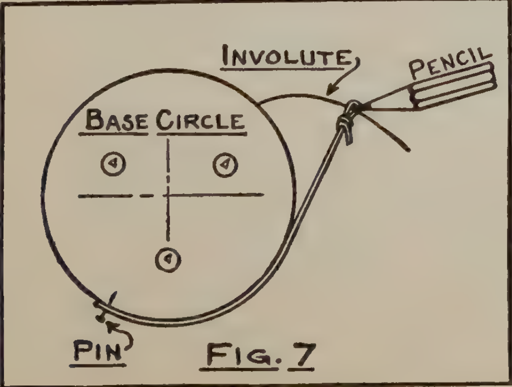


FIG. 7

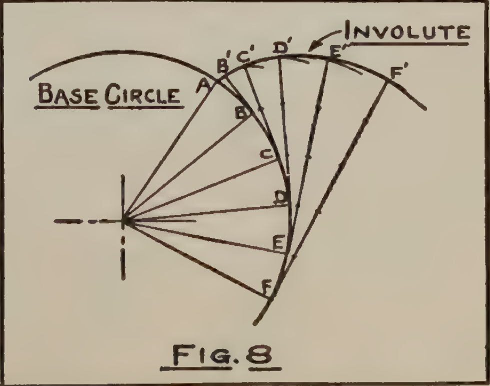


FIG. 8

having their centers on the base circles. The values of the radii of arcs for 15 degrees involute teeth have been carefully worked out and are given in the table on page 85. It will be noted that the values are for involute teeth having a pressure angle of 15 degrees. This is the angle most commonly used for cast gear teeth.

In cut gears the thickness of the tooth, theoretically speaking, equals the width of the space, altho in actual practice the space is made slightly greater so that the gears will run freely and without any tendency to bind. In cast gears the thickness is made considerably less than the space and the clearance is greater than in cut gears. This is to allow for irregularities in casting. The following proportions, in which *T* represents the thickness of a standard cut gear tooth, may be used for cast teeth: *thickness of tooth equals* .95T; *width of space,* 1.05T; *clearance,* .2T. The addendum is the same as in the Brown & Sharpe standard 14½ degree tooth.

GRANT'S ONDONTOGRAPH FOR INVOLUTE TEETH

No. of Teeth in the Gear	Radii for One Diametral Pitch; for Any Other Pitch Divide Values Given by that Pitch		Radii for One Inch Circular Pitch; for Any Other Pitch Multiply Values Given by that Pitch		No. of Teeth in the Gear	Radii for One Diametral Pitch; for Any Other Pitch Divide Values Given by that Pitch		Radii for One Inch Circular Pitch; for Any Other Pitch Multiply Values Given by that Pitch	
	Face Radius	Flank Radius	Face Radius	Flank Radius		Face Radius	Flank Radius	Face Radius	Flank Radius
10	2.28	0.69	0.73	0.22	28	3.92	2.59	1.25	0.82
11	2.40	0.83	0.76	0.27	29	3.99	2.67	1.27	0.85
12	2.51	0.96	0.80	0.31	30	4.06	2.76	1.29	0.88
13	2.62	1.09	0.83	0.34	31	4.13	2.85	1.31	0.91
14	2.72	1.22	0.87	0.39	32	4.20	2.93	1.34	0.93
15	2.82	1.34	0.90	0.43	33	4.27	3.01	1.36	0.96
16	2.92	1.46	0.93	0.47	34	4.33	3.09	1.38	0.99
17	3.02	1.58	0.96	0.50	35	4.39	3.16	1.39	1.01
18	3.12	1.69	0.99	0.54	36	4.45	3.23	1.41	1.03
19	3.22	1.79	1.03	0.57	37–40	4.20		1.34	
20	3.32	1.89	1.06	0.60	41–45	4.63		1.48	
21	3.41	1.98	1.09	0.63	46–51	5.06		1.61	
22	3.49	2.06	1.11	0.66	52–60	5.74		1.83	
23	3.57	2.15	1.13	0.69	61–70	6.52		2.07	
24	3.64	2.24	1.16	0.71	71–90	7.72		2.46	
25	3.71	2.33	1.18	0.74	91–120	9.78		3.11	
26	3.78	2.42	1.20	0.77	121–180	13.38		4.26	
27	3.85	2.50	1.23	0.80	181–360	21.62		6.88	

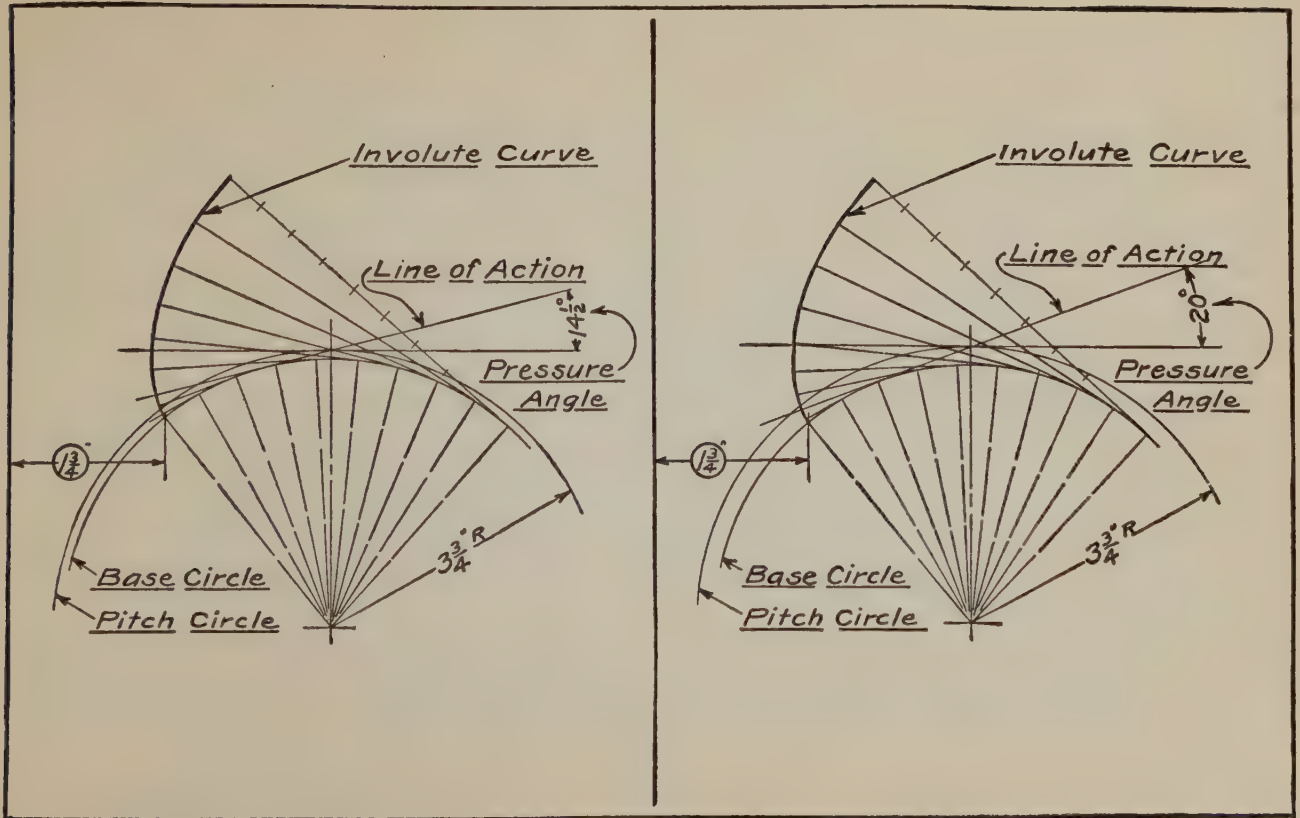
Note: For gears having more than 36 teeth one arc only is used.

SPECIFICATION—PROBLEM 16

Make a drawing of two Involute Curves as shown on the lay-out sheet, page 87, one with a pressure angle of 14½ degrees and the other with a pressure angle of 20 degrees. Scale, 12 inches equals 1 foot. The pitch circle is the same size in both cases. Show all construction lines and put in notes as indicated.

Proceed in each case as follows: Draw first the pitch circle. Then draw the line of action and the base circle tangent to it. Locate a starting point on the base circle as shown, from which the involute curve is to be drawn. From this point space off a number of divisions on the base circle; equal spaces of ½ inch each will do nicely in this case. Draw lines tangent to the base circle at these points. Assume the tangents as representing a piece of string in different positions as it is being unwound from the base circle. Lay off on each tangent line from its point of tangency a distance equal to the amount of string that is supposedly unwound. Assuming that the half-inch chords very nearly approximate the arcs, the required number of half-inch spaces may be used for this purpose. A line drawn thru these points with an irregular curve will complete the involute.

It is unnecessary and a waste of time to attempt to draw the exact involute curves in the drawing of a gear which is to have the teeth cut, as the form of the teeth is taken care of by the gear cutters which are a standardized article. To become familiar with the involute curve, however, and understand clearly how a variation in the pressure angle causes a change in the curve for a given pitch circle, it is well to draw one or two curves.



INVOLUTE CURVES

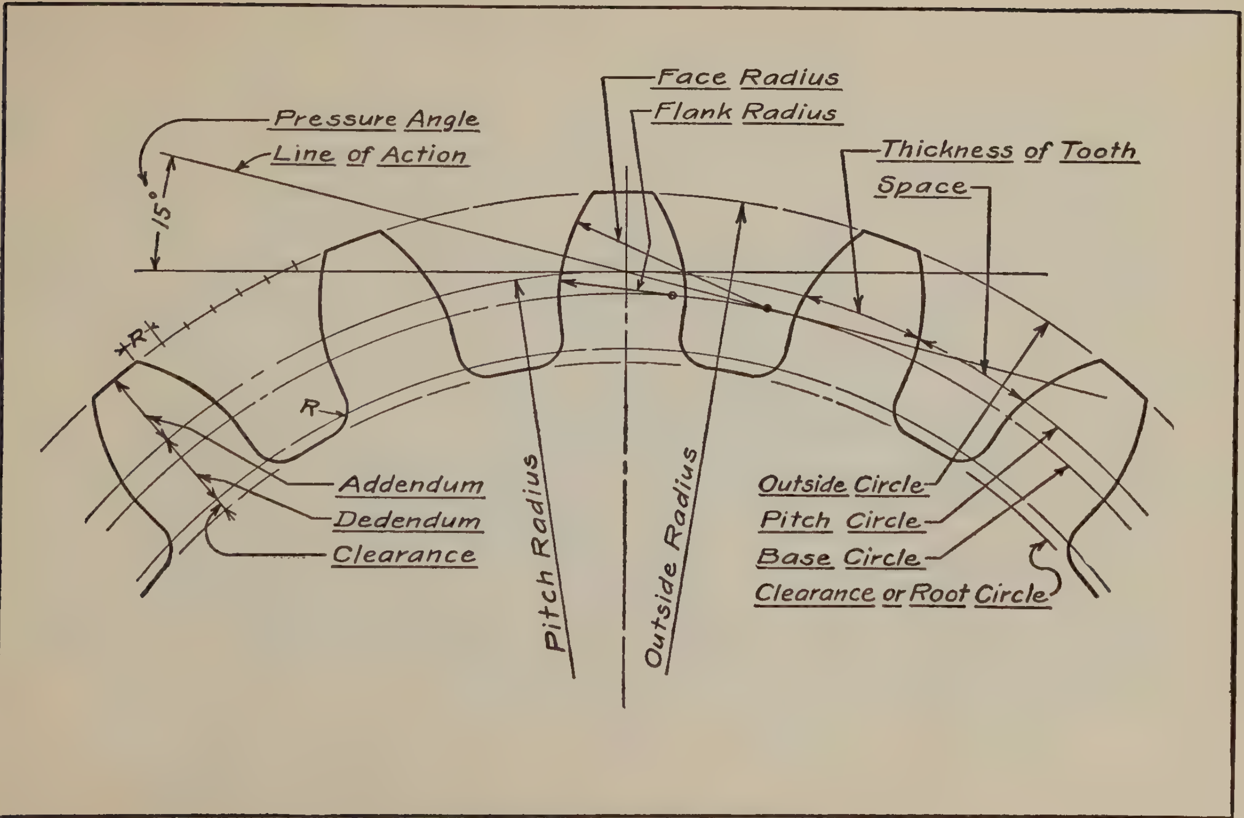
SPECIFICATION—PROBLEM 17

Make an outline drawing of Involute Gear Teeth for a gear having eighteen teeth of one diametral pitch, using Grant's Ondontograph for drawing the curves. With the exception of the pressure angle, use Brown & Sharpe tooth proportions. Scale, 12 inches equals 1 foot.

As most gears are cut, this drawing is to represent Brown & Sharpe cut teeth and is given to afford practice in laying out teeth on drawings of cut gears when this is necessary. A very accurate method of determining approximate gear tooth outlines was devised by Geo. B. Grant, and is known as Grant's Ondontograph. It is given on page 85. The curves are drawn by means of circular arcs having their centers on the base circle. In gears having 10 to 36 teeth inclusive, two arcs are used; in gears having 37 or more teeth one arc only is used.

To draw the teeth in this plate proceed as follows: Draw the outside, pitch, base, and root circles. On the pitch circle point off equal spaces representing the thickness of the tooth and the width of the space. With the proper face radius obtained from Grant's table, draw in the faces from the pitch circle to the outside circle. With proper flank radius, draw in the flanks from the pitch circle to the base circle. Draw straight radial flanks from the base circle to the dedendum circle and round them into the root circle with a radius equal to one-seventh of the space measured on the outside circle.

Grant's Ondontograph is especially useful in laying out the curves for teeth that are to be cast. In such drawings the thickness of the tooth, the width of the space, the clearance, the radii of the arcs, and the diameter of the base circle must be dimensioned. See page 84 for cast tooth proportions.



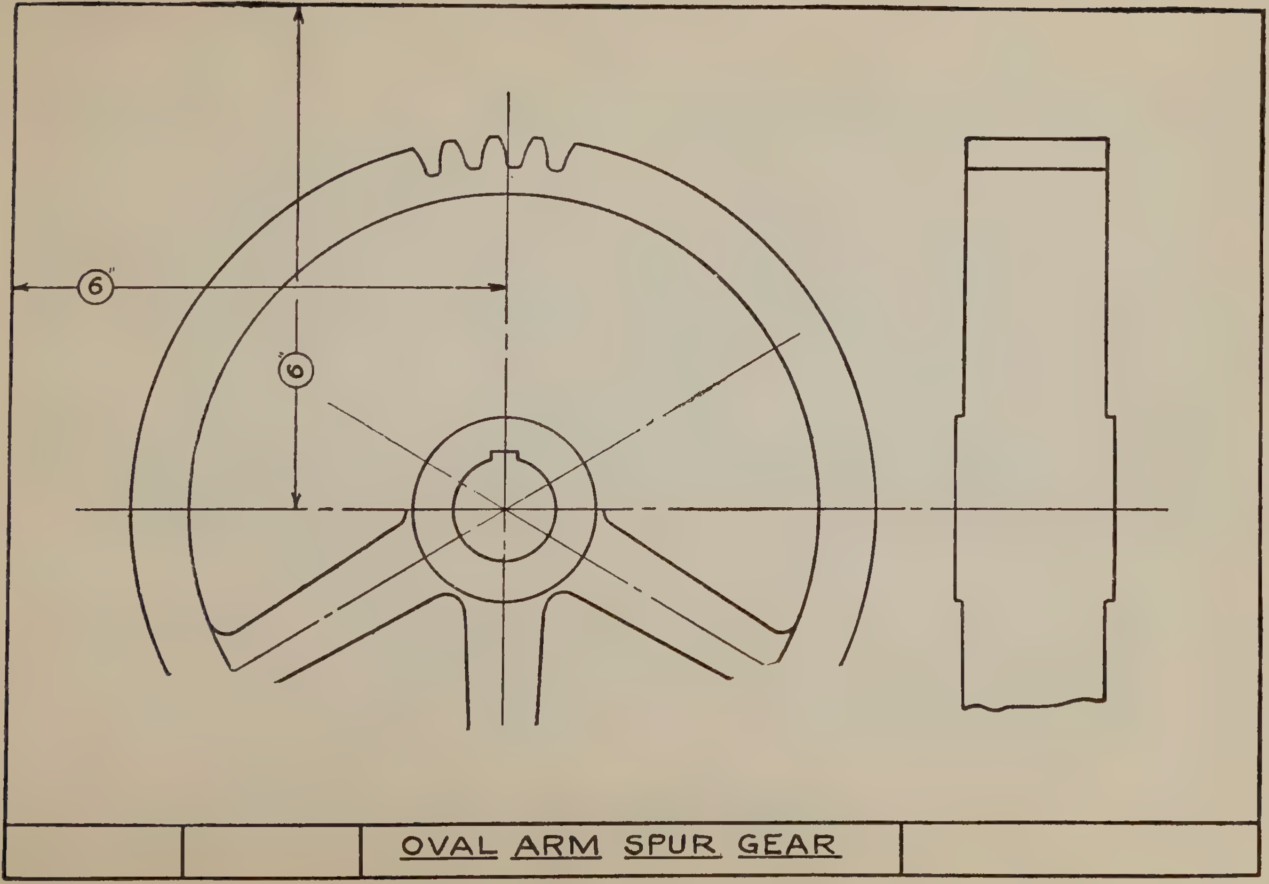
INVOLUTE GEAR TEETH
GRANT'S METHOD

SPECIFICATION—PROBLEM 18

Make a complete working drawing, showing all necessary dimensions, of a Spur Gear, with Brown & Sharpe involute cut teeth as suggested on the lay-out sheet, page 91. Scale, 12 inches equals 1 foot. Show the side view in section and an isolated section of the arms. Select one of the four types of gear arms as shown on page 95, and one of the following sizes of gears: 50 Teeth, 5 Diametral Pitch, 1½ inch Bore; 59 Teeth, 6 Diametral Pitch, 1¼ inch Bore. There are to be six arms in all cases. The dimensions of the arms and hubs, etc., may be worked out to the nearest thirty-second of an inch. The outline of the teeth, as shown on the lay-out sheet, need not be drawn, but the kind of tooth, the number of teeth, etc., must be specified. (See Specification—Problem 15.)

When a large and a comparatively small gear are in mesh, the smaller is generally referred to as the "pinion." Pinions are often made from a solid blank cut from cylindrical bar stock. Gears of a greater diameter than those ordinarily known as "pinions" are commonly lightened in weight by being shaped with their sides recessed to form a web, which connects the rim and the hub. As the gear becomes still larger in diameter, the increasing weight of the gear may be diminished by cutting or casting holes in the web or by using one of several types of arms for supporting the rim.

Gears with arms of oval section are very easily molded, are handsome in appearance, and altho they require somewhat more metal for the same strength than do the designs with the other types of arms, they are used very widely.

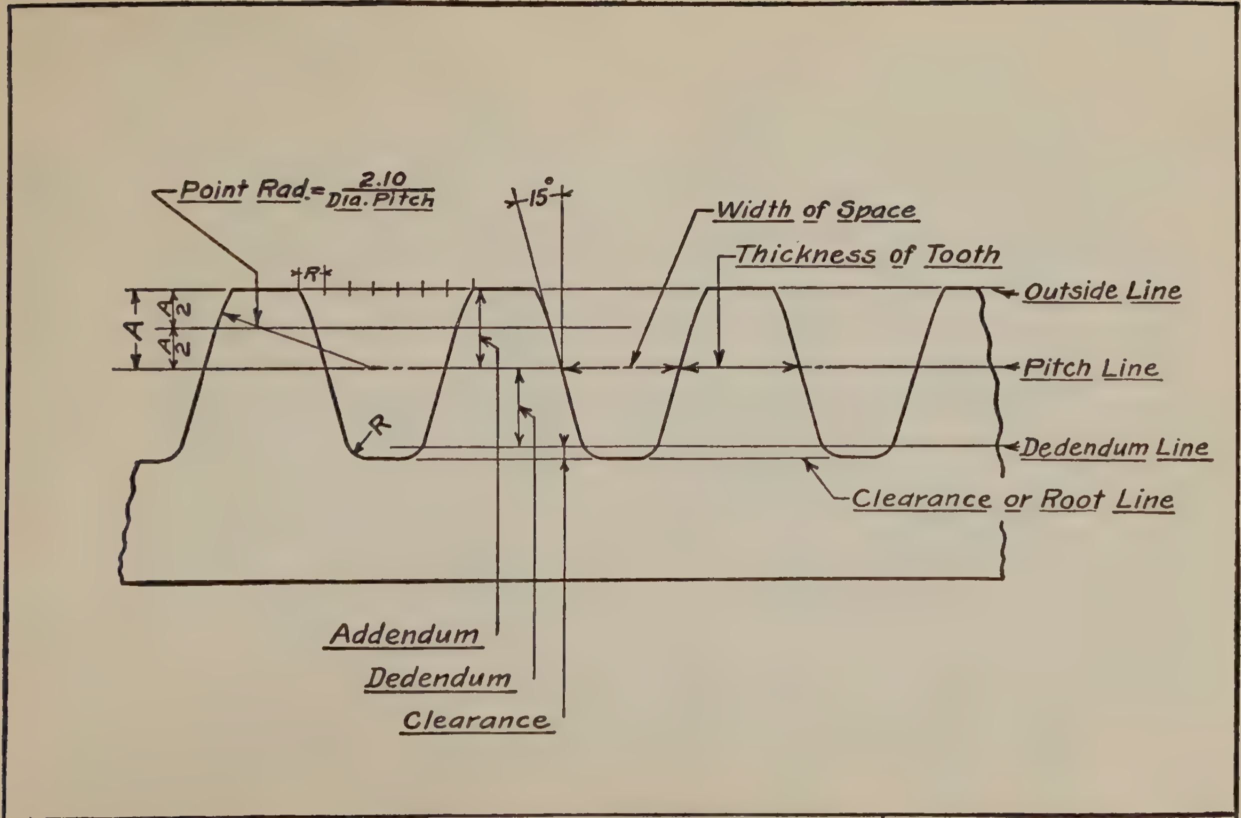

6"
6"
OVAL ARM SPUR GEAR

SPECIFICATION—PROBLEM 19

Make a drawing representing Involute Rack Teeth showing four teeth of one diametral pitch. Do not put in the actual dimensions of the parts but indicate all notes, etc., as shown on the lay-out sheet, page 93. Scale, 12 inches equals one foot.

The rack is laid out to engage gears with teeth drawn according to Grant's Ondontograph. The teeth are drawn with straight sides, from the fillet at the root line to a point midway between the pitch and outside lines, making angles of 75 degrees with the pitch line. The outer half of the face of the tooth is drawn with a circular arc having its center on the pitch line and a radius equal to 2.10 inches divided by the diametral pitch or 0.67 inch multiplied by the circular pitch. The radius of the fillet at the root of the tooth is taken as one-seventh of the tooth space measured on the outside line.

The thickness of the metal under the teeth depends upon the use of the rack and the method of fastening it. In this drawing it may be made equal to the tooth thickness. Racks are used for a variety of purposes and are intended primarily for converting circular motion into straight-line motion or vice versa.



INVOLUTE RACK TEETH

TABLE OF TOOTH DIMENSIONS 14½° SYSTEM

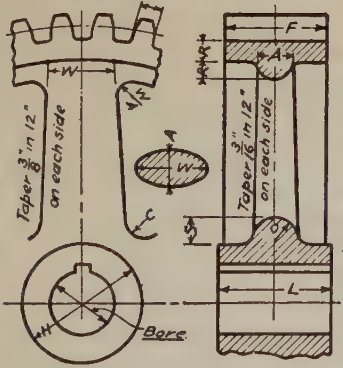
Diametral Pitch	Thickness of Tooth	Addendum	Clearance	Whole Depth
1	1.5708	1.0000	.1571	2.1571
1½	1.0472	.6667	.1047	1.4381
2	.7854	.5000	.0785	1.0785
2½	.6283	.4000	.0628	.8628
3	.5236	.3333	.0524	.7190
4	.3927	.2500	.0393	.5393
5	.3142	.2000	.0314	.4314
6	.2618	.1667	.0262	.3595
7	.2244	.1429	.0224	.3081
8	.1963	.1250	.0196	.2696
9	.1745	.1111	.0175	.2397
10	.1571	.1000	.0157	.2157
12	.1309	.0833	.0131	.1798
14	.1122	.0714	.0112	.1541
16	.0982	.0625	.0098	.1348
18	.0873	.0555	.0087	.1198
20	.0785	.0500	.0078	.1079
22	.0714	.0455	.0071	.0980
24	.0654	.0417	.0065	.0899
26	.0604	.0385	.0060	.0829
28	.0561	.0357	.0056	.0770
30	.0524	.0333	.0052	.0719
32	.0491	.0312	.0049	.0674

TABLE OF TOOTH DIMENSIONS STUB TOOTH SYSTEM

Diametral Pitch	Thickness of Tooth	Addendum	Clearance	Whole Depth of Tooth
4/5	.3927	.2000	.0500	.4500
5/7	.3142	.1429	.0357	.3214
6/8	.2618	.1250	.0312	.2812
7/9	.2244	.1111	.0278	.2500
8/10	.1963	.1000	.0250	.2250
9/11	.1745	.0909	.0227	.2045
10/12	.1571	.0833	.0208	.1875
12/14	.1309	.0714	.0179	.1607

DIMENSIONS OF SPUR GEARS WITH SIX ARMS.

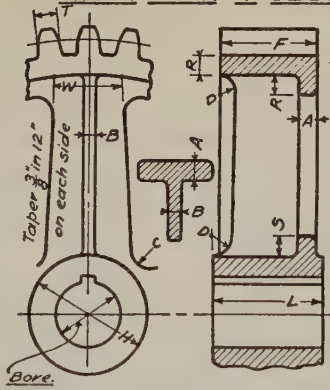
GEAR WITH OVAL SECTION ARMS.



W
R
A
W
F
C
D
S
L
H
Bore.
Taper 3/8" in 12" on each side
Taper 3/16" in 12" on each side

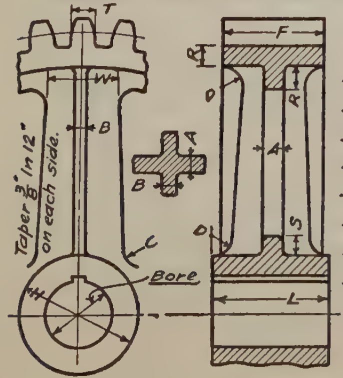
T = Thickness of tooth.
A = 2T
W = 4T
R = T
F = 5T to 6T
H = 1.8 Bore
L = F + .025 P.Dia.
S = 1.4T Minimum
Rad C and D to suit.
Rad.C Minimum = 1/4"

GEAR WITH T SECTION ARMS.



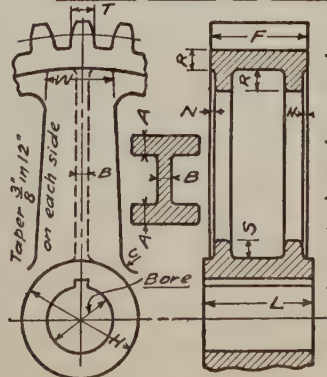
T = Thickness of tooth.
A = T
W = 4.5T
B = .6T
R = T
F = 5T to 6T
H = 1.8 Bore
L = F + .025 Pitch Dia.
S = 1.5T Minimum
Rad.D = T
Rad.C to suit Min. 1/4"

GEAR WITH + SECTION ARMS.



T = Thickness of tooth.
A = T
W = 5T
B = .6T
R = T
F = 5T to 6T
H = 1.8 Bore
L = F + .025 P.Dia.
S = 1.5T Minimum
Rad.D = T
Rad.C to suit. Min. 1/4"

GEAR WITH H SECTION ARMS.



T = Thickness of tooth
A = T
W = 5T
B = .6T
R = T
F = 5T to 6T
H = 1.8 Bore
L = F + .025 P.Dia.
S = 1.5T Minimum
N = .5T
Rad.C to suit. Min. 1/4"

BEVEL GEARS

Bevel gears are used to connect shafts that are not parallel to each other and most generally for shafts whose axes intersect. The motion of a bevel gear is the same as that of two friction cones. See Fig. 1, page 97. These cones are known as the "pitch cones" and exist geometrically in all bevel gears. The "pitch circle" of a bevel gear is the circle represented by the base of its pitch cone; and the diameter of this circle is the "pitch diameter" of the gear. Problems involving the relation between the pitch diameter, diametral pitch, number of teeth, etc., are the same as in the spur gear.

Bevel gears are often shown in outline or assembly drawings as plain or smooth cones without teeth as in Fig. 2. In working drawings they are represented in sectional views, which show the teeth as in Fig. 3, and must be fully dimensioned. To lay out a pair of bevel gears proceed as follows: Referring to Fig. 4, draw the pitch cones *a-b-c* and *c-b-d*. The pitch diameter of the small gear is *a-c;* of the large gear, *c-d*. Draw *e-g* and *h-k* at right angles to *a-b*. Make distance *a-m* about one-third of *a-b*. Draw similar lines at points *c, n, o,* and *d*. Lay off distance *a-g* equal to addendum and *a-e* equal to dedendum plus clearance. Lay off similar distances from points *d* and *c*. Draw lines from points *e, g, r, s,* etc., to point *b*.

When it is desired to obtain the form of the teeth, as might be necessary in case a wood pattern is to be made for molding purposes, the exact profile of the tooth at the large and small ends is developed on a plane surface from which templets are made. To develop the profiles of the teeth of the large gear in Fig. 4, at the large end of the tooth, draw the *profile-construction-pitch-circle* for the large end with radius *u-c* and center at *u*. With same center draw the *"profile addendum circle," "profile dedendum circle,"* and *"profile root circle."* Draw the teeth, using Grant's

Ondontograph, selecting radii as for the number of teeth in a spur gear of pitch radius *u-c*. To develop the profile of the teeth of the large gear at the small end of the tooth, draw the profile-construction-pitch-circle for the small end with radius *u-v* equal to *t-n*, and center at *u*. Draw circles and proceed as for large end of the tooth, selecting radii from Grant's Ondontograph as for a spur gear of pitch radius *u-v*. If the teeth are to be cast, proportions as for cast teeth in spur gears should be used in laying out the profiles.

FIG.-1

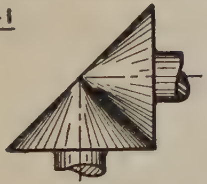


FIG.-2

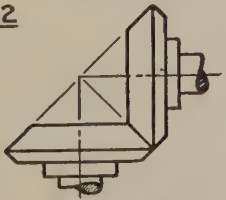


FIG.-3

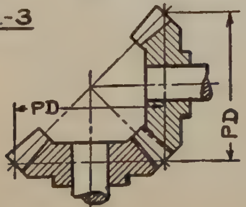
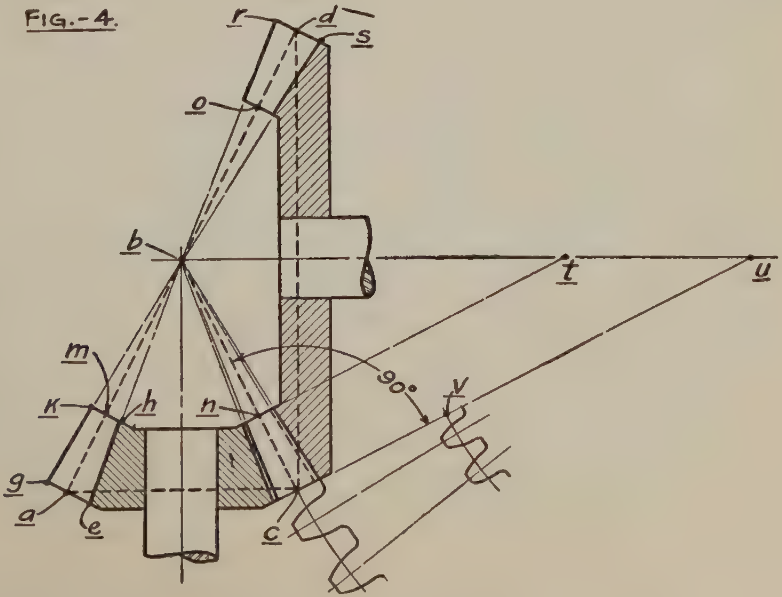


FIG.-4.



SPECIFICATION—PROBLEM 20

Make a working drawing of the Bevel Gear and Pinion as shown on the lay-out sheet, page 99. Scale, 12 inches equals 1 foot. Draw first the pitch cones and proceed as described on page 96. Show all dimensions and indicate the angles with notes as shown. The letters *C, E, D* and *S* have reference to the trigonometric formulae given below and need not be placed on the drawing.

A pair of bevel gears can be laid out as described on page 96, but in order to compute the angles which must be given on a complete working drawing, a knowledge of trigonometry is necessary.

TRIGONOMETRIC FORMULAE FOR BEVEL GEARS WITH SHAFTS AT 90 DEGREES

$$\text{Tan. } A \text{ equals } \frac{\text{No. of teeth in small gear}}{\text{No. of teeth in large gear}}$$

$$\text{Tan. } B \text{ equals } \frac{\text{No. of teeth in large gear}}{\text{No. of teeth in small gear}}$$

$$C \text{ equals } \frac{\text{Pitch Diameter}}{\text{2 times Sine of center angle}}$$

$$\text{Tan. } D \text{ equals } \frac{\text{Addendum}}{\text{Pitch Cone Radius}}$$

$$\text{Tan. } E \text{ equals } \frac{\text{Dedendum plus Clearance}}{\text{Pitch Cone Radius}}$$

A plus *D* equals *F*

A minus *E* equals *G*

$$S \text{ equals } \frac{\text{Cosine of center angle}}{\text{Diametral Pitch}}$$

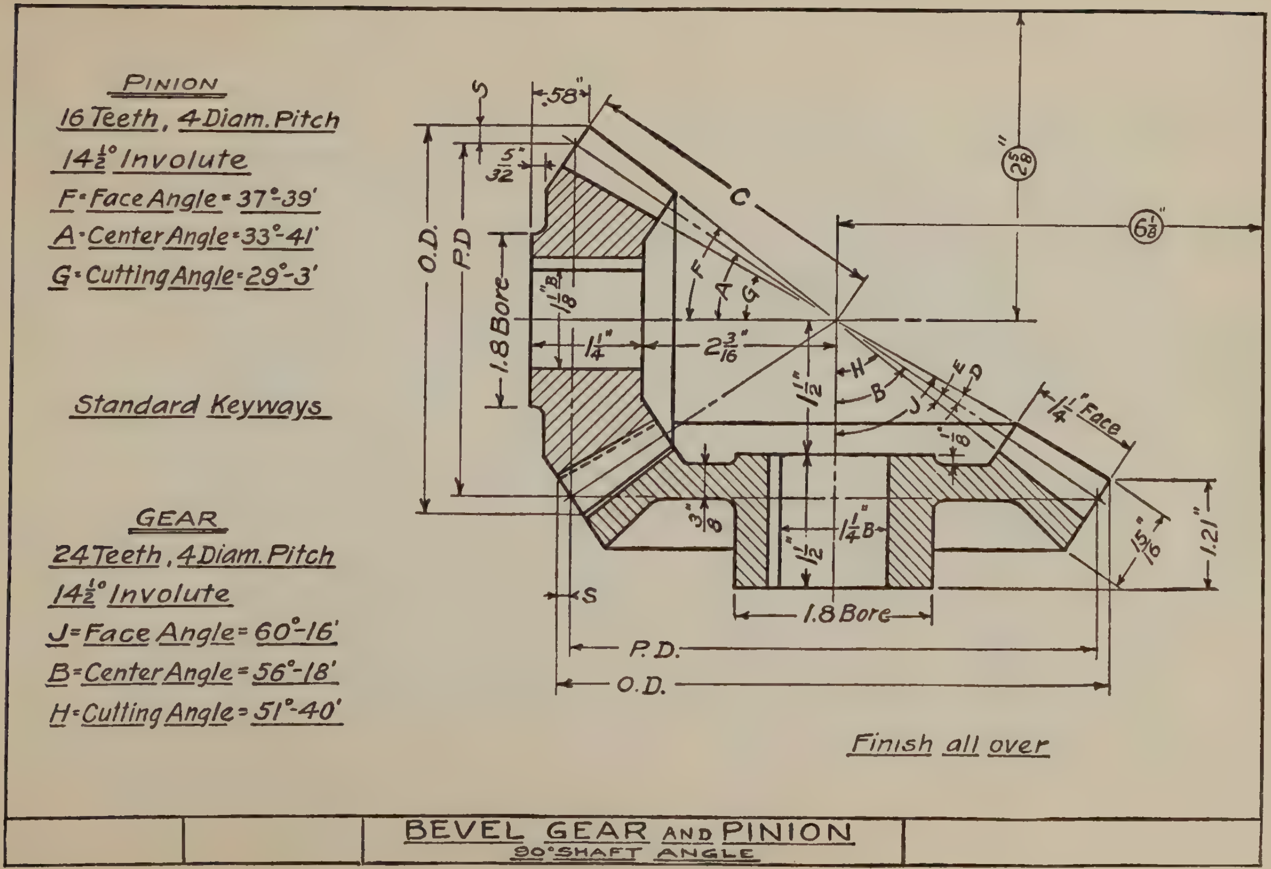
Outside diameter equals 2*S* plus Pitch Diameter

C is called the Pitch Cone Radius

D is called the Angle Increment

E is called the Angle Decrement

2*S* is called the Diameter Increase


PINION
16 Teeth, 4 Diam. Pitch
14½° Involute
F = Face Angle = 37°-39'
A = Center Angle = 33°-41'
G = Cutting Angle = 29°-3'
Standard Keyways
GEAR
24 Teeth, 4 Diam. Pitch
14½° Involute
J = Face Angle = 60°-16'
B = Center Angle = 56°-18'
H = Cutting Angle = 51°-40'
S
.58"
5/32"
C
2 5/8"
6 1/8"
O.D.
P.D
1.8 Bore
1 1/8" B
1 1/4"
2 3/16"
F
A
G
H
B
J
E
D
1 1/2"
1 1/4" Face
1/8"
3/8"
1 1/4" B
1 1/2"
15/16"
1.21"
S
1.8 Bore
P.D.
O.D.
Finish all over
BEVEL GEAR AND PINION
90° SHAFT ANGLE

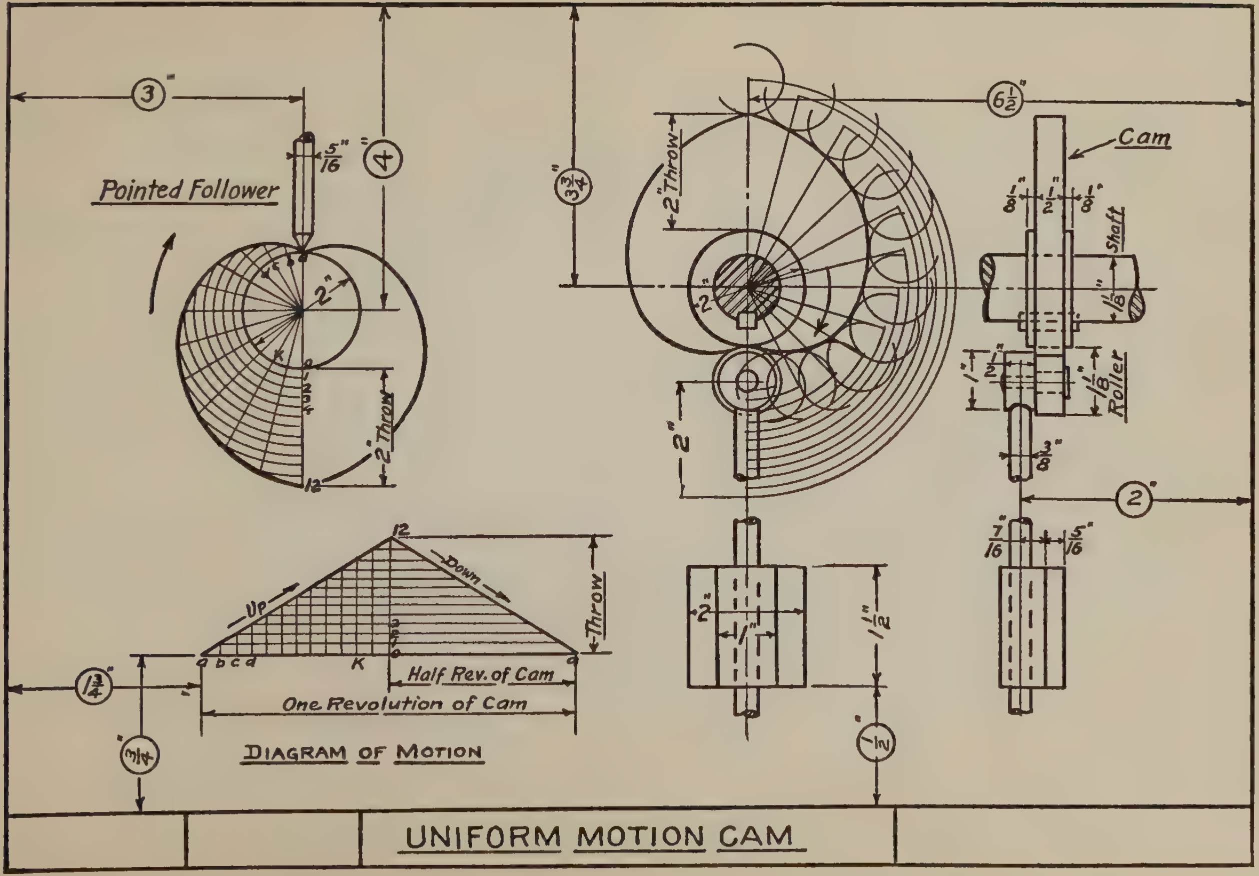
GROUP 3. DEVICES CONTROLLING MOTION

SPECIFICATION—PROBLEM 21

A cam is a mechanical device provided with curved surfaces or grooves for imparting or communicating motion to another machine part thru the sliding or rolling contact of a follower which is brought to bear upon or engage with the curved surfaces or grooves. Most cams rotate and the driven member has a reciprocating or swinging motion. Cams are used in many forms of machines as they can be designed to give almost any action required.

Problem 1.—Make a complete lay-out of the Uniform Motion Cam with a pointed follower and the diagram of motion as shown on the left half of the lay-out sheet, page 101. Scale, 12 inches equals 1 foot. To draw one-half of the curve proceed as follows: (1) Draw the circle representing the minimum diameter of the cam which in this case has a radius of one inch. (2) Divide the left half of the circle into any convenient number of equal parts and draw radial lines. (3) On the vertical center line, lay off a distance equal to the throw and divide it into the same number of equal parts. (4) Through these divisions, and with the same center used in step number 1, draw circles intersecting the radial lines in the following order: Circle numbered *1* intersects radial line *b,* circle numbered *2* intersects radial line *c,* etc. These intersections will establish points on the required curve. The other half of the cam is laid out in the same manner. The diagram of motion may be drawn to any convenient size or proportion.

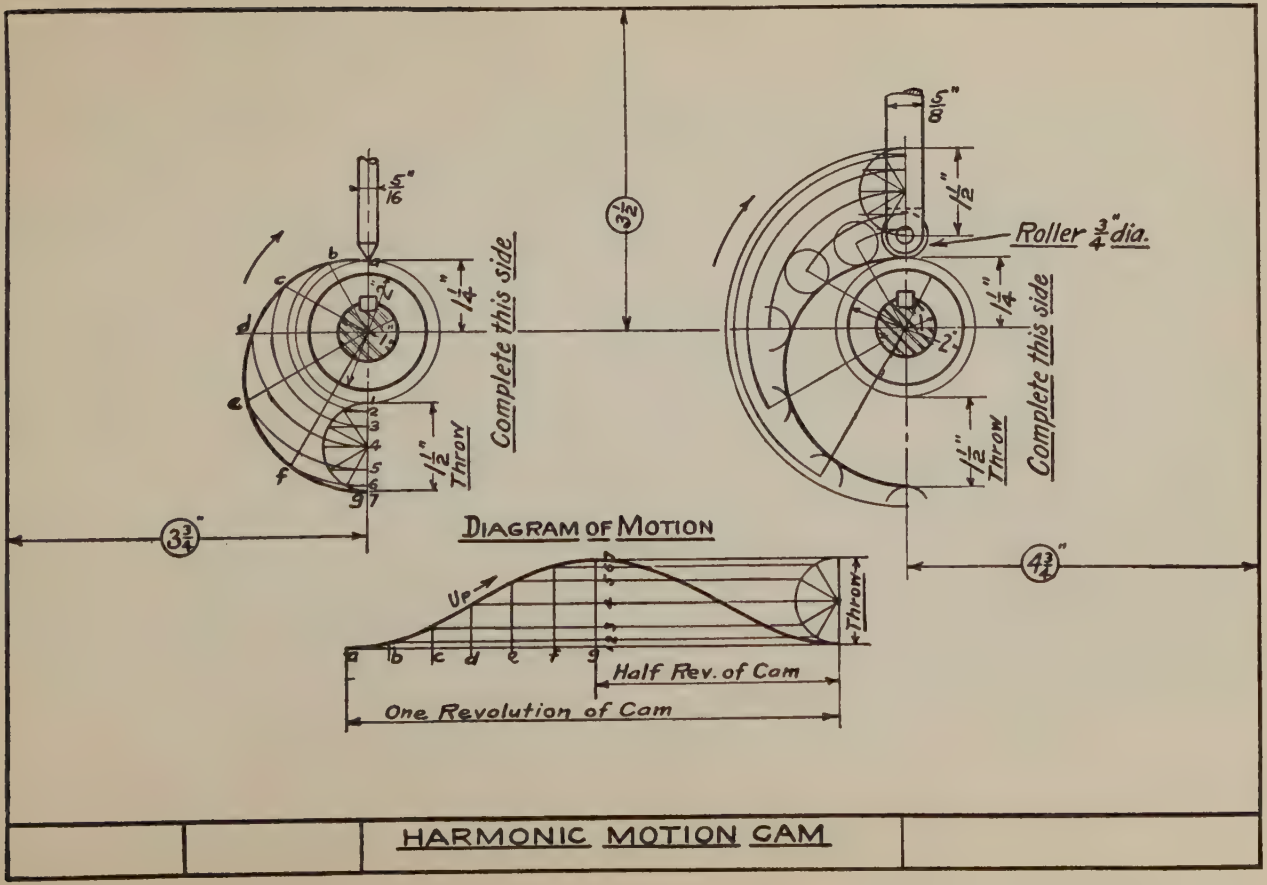
Problem 2.—Make a complete drawing of a Uniform Motion Cam with a roller follower, as shown on the right half of the lay-out sheet. Scale, 12 inches equals 1 foot. In this drawing the points marking the position of the center of the roller at various intervals in the rotation of the cam must be determined. With these points as centers and with a radius equal to that of the roller, describe arcs. The required cam curve must be drawn tangent to these arcs.


3"
4"
5"/16
Pointed Follower
2"
2" Throw
12
3 3/4"
2" Throw
6 1/2"
Cam
1/8"
1/2"
1/8"
Shaft
1 1/8"
Roller
1"
1/2"
1 1/8"
3/8"
2"
2"
7"/16
5"/16
2"
1"
1 1/2"
1 1/2"
Up
Down
Throw
a b c d
K
Half Rev. of Cam
One Revolution of Cam
1 3/4"
3/4"
DIAGRAM OF MOTION
UNIFORM MOTION CAM

SPECIFICATION—PROBLEM 22

Make two complete lay-outs of a Harmonic Motion Cam, one with a pointed follower and the other with a roller follower. Draw also the diagram of motion. Scale, 12 inches equals 1 foot. This cam is laid out much like the uniform motion cam with this exception: Instead of dividing the stroke into equal parts it must be divided into parts that increase gradually from point 1 to 4 and then decrease gradually from point 4 to point 7. This is done as shown in the lay-out sheet. The diagram may be laid out to any convenient size or proportion.

The heart cam or uniform motion cam in Problem 21 is designed to give the follower a uniform motion from the beginning to the end of its stroke. This uniform motion, however, is suitable for slow speeds only because if the speed is increased beyond a certain point a shock occurs at the beginning and at the end of each stroke. When the follower does not necessitate a certain kind of motion, and the only requirement is that it be moved a given distance during a revolution or part revolution of the cam, the curvature of the cam should be laid out to start and stop the follower as easily as possible, so as to avoid shocks. In the crank or harmonic motion cam, the follower is gradually accelerated to the maximum velocity and then gradually retarded; moving slowest at the beginning and the end of its stroke and at its maximum speed near the middle of the stroke. This avoids shocks and counts for smoothness of operation.

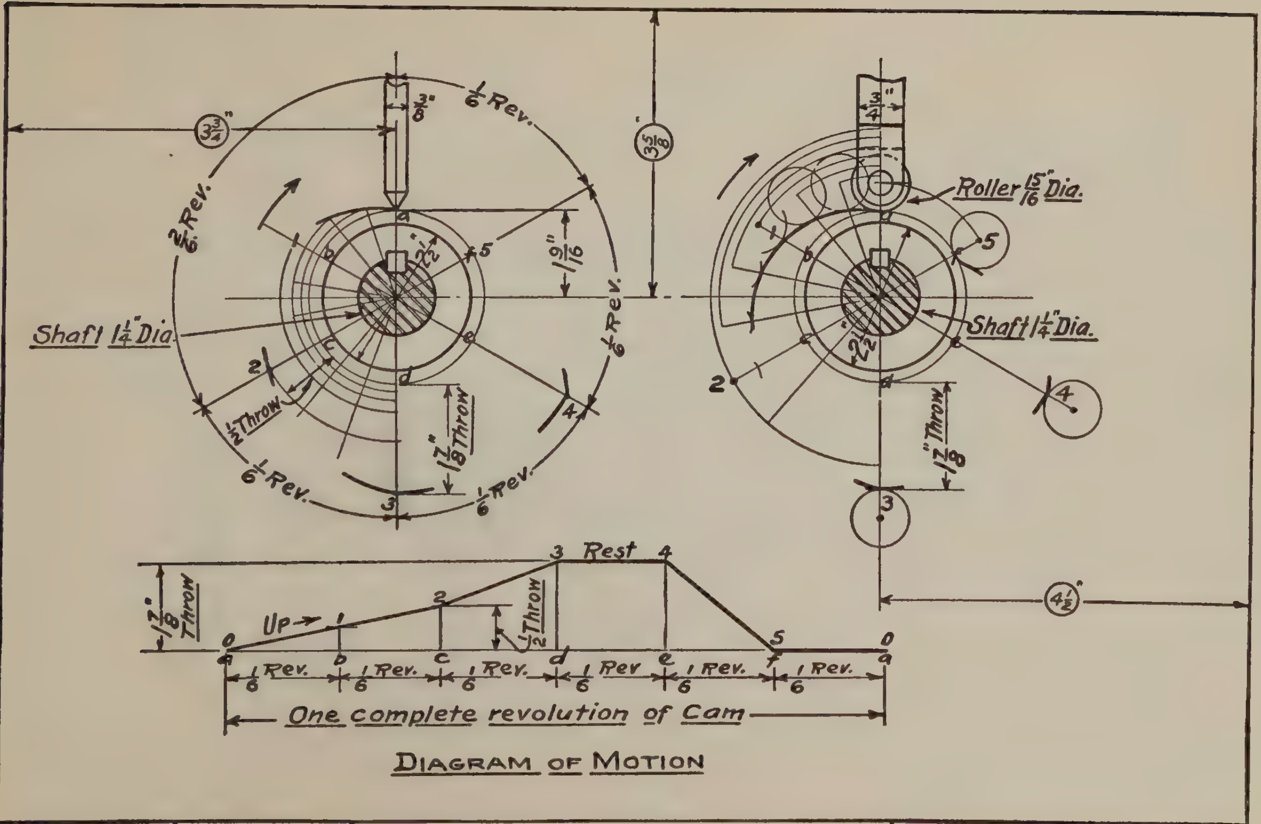

5/16"
b
c
d
e
f
g
1
2
3
4
5
6
7
1 1/4"
1 1/2" Throw
Complete this side
3 1/2
3 3/4"
5/8"
1 1/2"
Roller 3/4" dia.
1 1/4"
2"
1"
1 1/2" Throw
Complete this side
4 3/4"
DIAGRAM OF MOTION
Up
Throw
a
b
c
d
e
f
g
Half Rev. of Cam
One Revolution of Cam
HARMONIC MOTION CAM

SPECIFICATION—PROBLEM 23

Draw the diagram of motion and two complete lay-outs of a Variable Motion Cam; one with a pointed follower and the other with a roller follower. Scale, 12 inches equals 1 foot.

Study the diagram carefully before beginning to draw the cam. The motion of the cam should be considered in parts of a complete revolution as $\frac{1}{4}$ revolution, or 45 degrees, $\frac{1}{3}$ revolution or 120 degrees, etc. The motion of the follower should be considered in parts of the total throw as, one-half throw or $\frac{15}{16}$ inch. The diagram indicates that the motion is divided into five periods, three of uniform motion and two rest periods.

Draw first the circle representing the minimum diameter of the cam and the vertical center line which locates point *a*. Measuring to the left from this center line, lay off and draw a radial line representing the part of the revolution taken up by the first period of motion, which is according to the diagram one-third of the total revolution, or 120 degrees on the circle. Lay off from point *a* on the vertical center line the part of the stroke which is taken up by this period which is according to the diagram one-half the stroke or $\frac{15}{16}$ inch. Divide the 120 degrees on the circle by any number of radii, equally distributed, and divide the $\frac{15}{16}$ inch on the center line into the same number of equal parts. Thru these divisions of the stroke, and from the center of the cam, draw circles intersecting the radial lines. The points of intersection are points on the required curve for the first period of motion. Proceed in a similar manner with the next period and so on. The curves representing the rest periods are circular arcs drawn from the center of the cam. The diagram may be drawn to any convenient size or proportion.



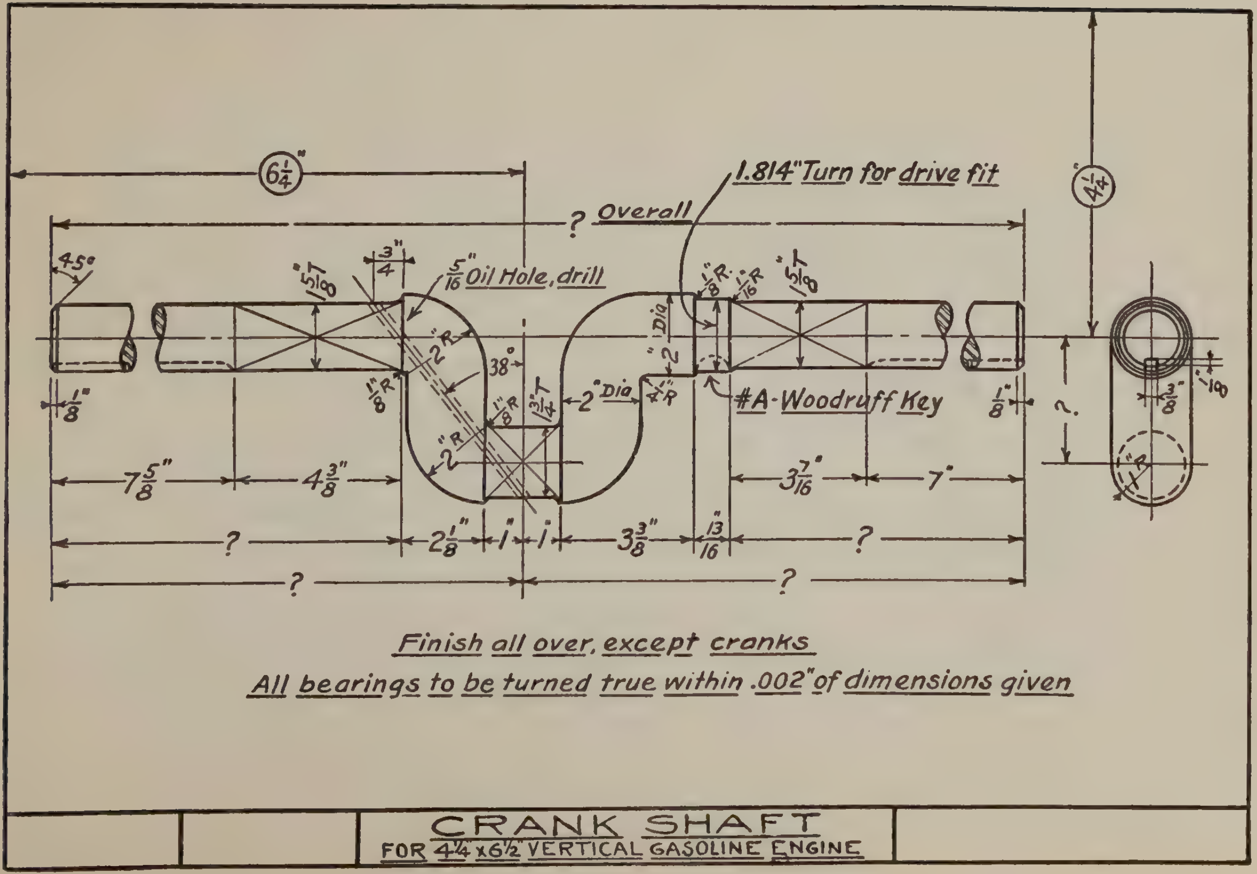
VARIABLE MOTION CAM

SPECIFICATION—PROBLEM 24

Make a complete working drawing of the Crank Shaft as shown on the lay-out sheet, page 107. Scale, 6 inches equals 1 foot. Put in all dimensions and necessary notes.

The crank shaft is of the type used in stationary gasoline engines. It is forged of steel having from .2% to .3% carbon and a tensile strength of 60,000 to 70,000 lbs. It rotates in two bearings in a crank case and in conjunction with the connecting rod converts the reciprocating motion of the piston into rotary motion of the fly-wheels. The bearing surfaces are indicated by the light cross lines and the fly-wheels are secured one near each end of the shaft by means of keys. The timing gear which operates the valve mechanism is mounted on the shaft with a Woodruff key. The gear is reamed with a standard reamer and the shaft is turned slightly larger so as to afford a driving fit. The long oil hole is to allow oil to flow from the main bearing to the connecting rod bearing. See Problem 27. The parts of the crank shaft that connect the shafts proper with the crank pin or connecting rod pin are known as cranks, crank cheeks, crank throws, or crank arms.

The crank shaft problem was taken from drawings contributed by the Worthington Pump Co., Gas Engine Division, Cudahy, Wisconsin.



CRANK SHAFT
FOR 4¼ x 6½" VERTICAL GASOLINE ENGINE

SPECIFICATION—PROBLEM 25

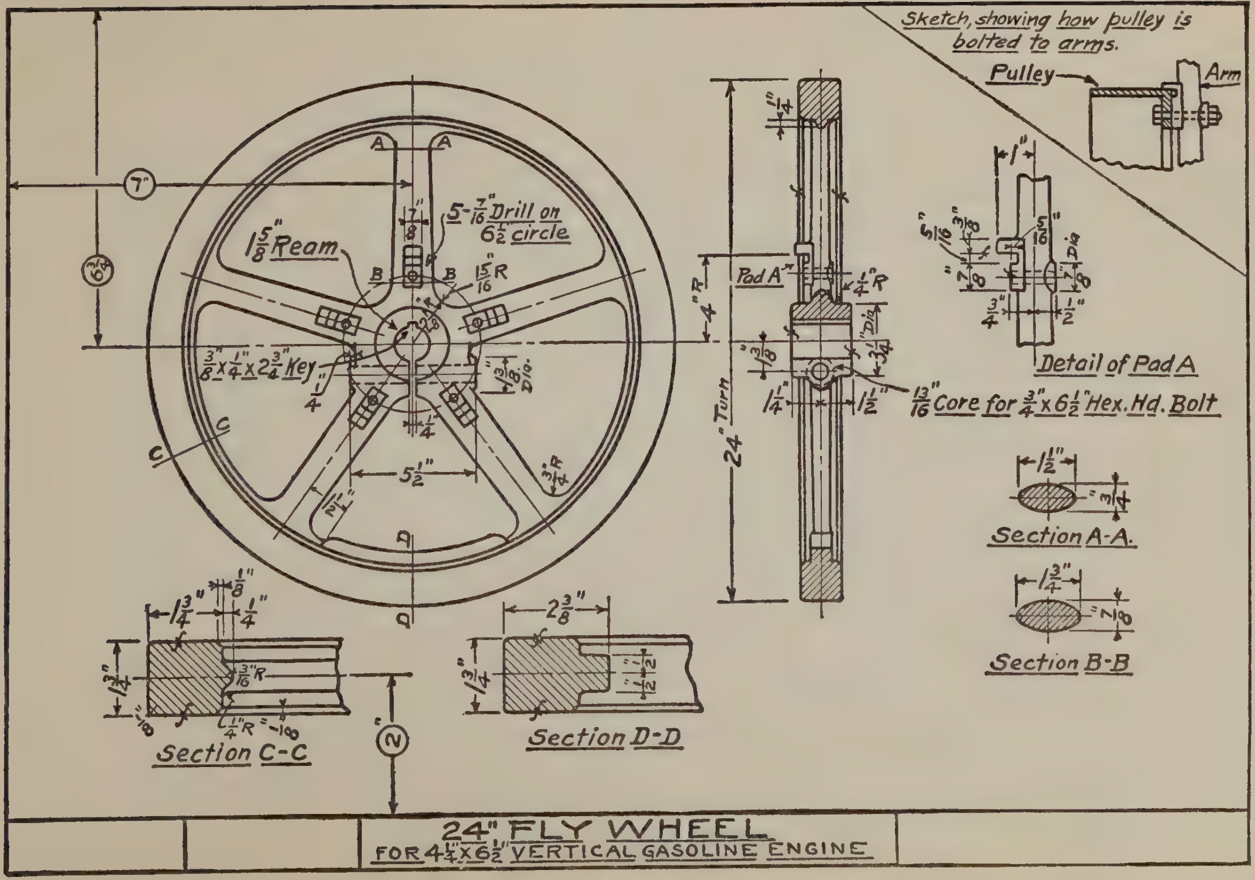
On the large-size sheet make a complete working drawing of the 24-inch Fly-Wheel as shown on the lay-out sheet, page 109. Show two views of the wheel at a scale of 6 inches equals 1 foot, and two isolated sections of the rim and arms at a scale of 12 inches equals 1 foot. The separate detail view of the pad should be omitted and dimensions pertaining to it placed directly on the side view of the wheel. The bolt need not be drawn, as it is a standard size machine bolt. Show all necessary dimensions and notes.

The fly-wheel in the drawing is typical of those used on the pulley side of small stationary gasoline engines. Nearly every one who has ever spun a top or owned a bicycle knows that if a wheel or cylindrical shaped object is spun about its axis it will continue to spin for some time. This principle is made use of in engine construction for by the use of fly wheels the intermittent power stroke of the piston is stored up in the momentum of the fly wheels, which causes the engine to revolve at a uniform rate of speed and provide a steady flow of power.

The pulley (not shown) is without a hub and consists of a rim which has an internal flange at one end. It is bolted thru the flange to the arms of the fly-wheel. The arms have small projections or pads on them which are bored out to receive the outside diameter of the pulley rim and faced true where the flange is bolted to them. See sketch on lay-out sheet.

The wheel is held to the shaft by means of a slotted hub and bolt and a key. The hole for the bolt is cored because it could not very well be drilled. The rim has a counterweight cast between two of its arms, to counter balance the weight of the crank pin and crank arms. The keyseats in the fly-wheel and the crank shaft must be so placed that the counterweight is directly opposite the crank pin when the wheels are keyed to the shaft.

This problem was taken from drawings contributed by the Worthington Pump Co., Gas Engine Division, Cudahy, Wisconsin.


Sketch, showing how pulley is bolted to arms.
Pulley
Arm
7"
6¼"
1⅝" Ream
5-7/16" Drill on 6½" circle
7/8"
A
A
B
B
15/16" R
3/8" x 1/4" x 2¾" Key
1/4"
1⅜" Dia.
1/4"
5½"
1½"
3/4" R
C
C
D
D
24" Turn
4" R
1/4"
Pad A
1/4" R
3¼" Dia
1⅜"
1¼"
1½"
13/16" Core for 3/4" x 6½" Hex. Hd. Bolt
1"
5/16"
3/8"
5/16"
7/8"
7/8" Dia
3/4"
1/2"
Detail of Pad A
1½"
3/4"
Section A-A.
1¾"
7/8"
Section B-B
1¾"
1/8"
1/4"
1½"
3/16" R
1/4" R
1/8"
1/8"
Section C-C
2"
2⅜"
1¾"
1/2"
1/2"
Section D-D
24" FLY WHEEL
FOR 4¼" X 6½" VERTICAL GASOLINE ENGINE

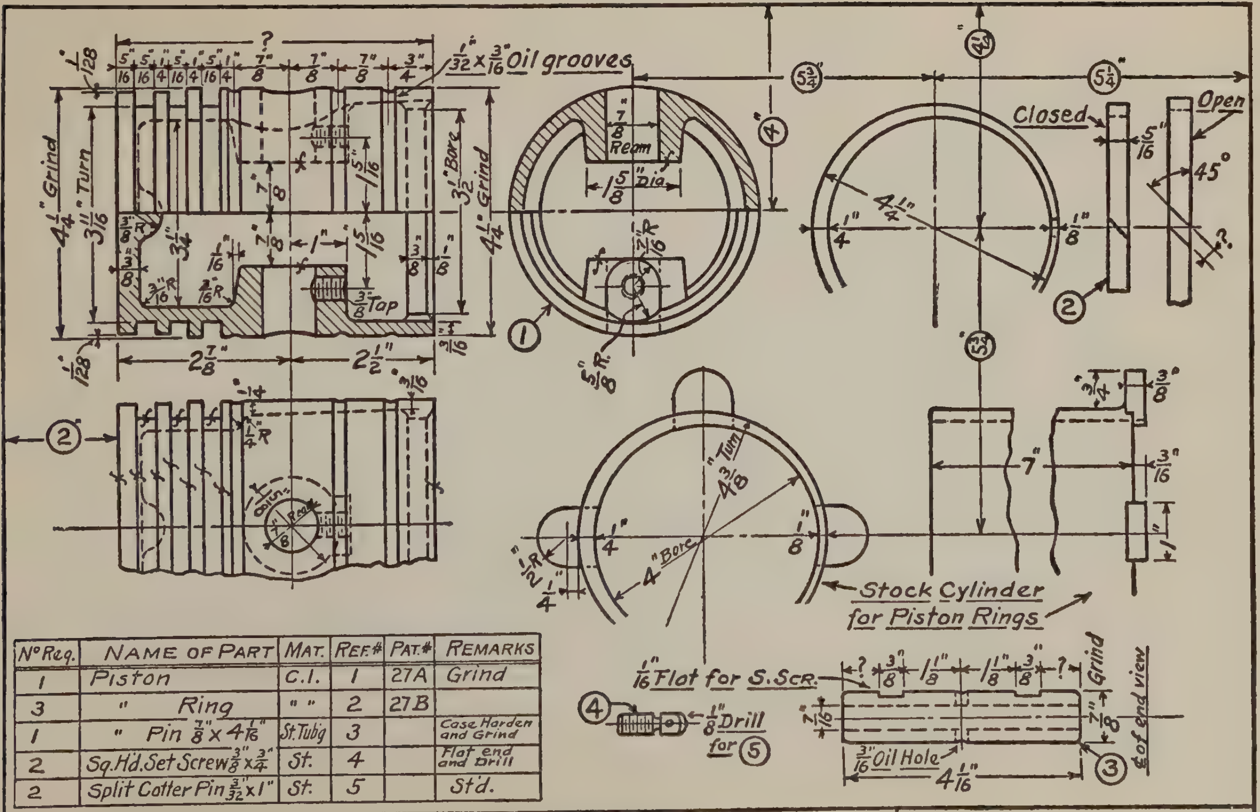
SPECIFICATION—PROBLEM 26

On the large size sheet make a complete detail drawing including a bill of material, of the gas engine Piston as shown on the lay-out sheet, page 111. Scale, 12 inches equals 1 foot. All views are to be completed.

This type of piston fits into the cylinder of a gasoline engine. It is connected to the crank shaft by means of the connecting rod and the piston pin, and moves up and down in the cylinder as the crank shaft revolves. Thru the motion of the piston the explosive gas is drawn into and then compressed in the cylinder, when combustion takes place and the piston receives the impulse of the expanding gases by which force it is moved and in turn impels the crank shaft. Because of the difference in the expansion of the piston and the cylinder, the piston cannot be fitted very snugly into the cylinder or it might bind or become tight while in operation. In order to keep the gases from passing between the piston and the cylinder walls, compression rings are fitted into grooves cut in the piston. The rings are turned somewhat larger in diameter than the cylinder bore after which a piece is cut out of their circumference so that when they are pressed together they will just fit into the cylinder. This causes them to exert a constant pressure against the cylinder walls and prevents leakage. To save time in manufacture, the rings are generally machined from a long casting or "stock cylinder." They are turned eccentric so that they will retain the true shape of a circle when they are pressed together. The width of the cutter to slot the rings should be dimensioned on the extra side view which shows the ring open.

While being machined the piston is held in a chuck from the inside of the open end and supported with a lathe-center at the other end. An internal strengthening rib or ring is cast at the open end to keep it from being distorted while being chucked and a boss or projection is cast on the inside of the other end to provide metal for a center-hole.

Drawings from which this problem were taken were furnished by the Worthington Pump Co., Gas Engine Division, Cudahy, Wisconsin.



Nº Req.	NAME OF PART	MAT.	REF.#	PAT.#	REMARKS
1	Piston	C.I.	1	27A	Grind
3	" Ring	" "	2	27B	
1	" Pin $\frac{7}{8}''\times 4\frac{1}{16}''$	St. Tub'g	3		Case Harden and Grind
2	Sq. Hd. Set Screw $\frac{3}{8}''\times\frac{3}{4}''$	St.	4		Flat end and Drill
2	Split Cotter Pin $\frac{3}{32}''\times 1''$	St.	5		St'd.

PISTON

FOR $4\frac{1}{4}''\times 6\frac{1}{2}''$ VERTICAL GASOLINE ENGINE

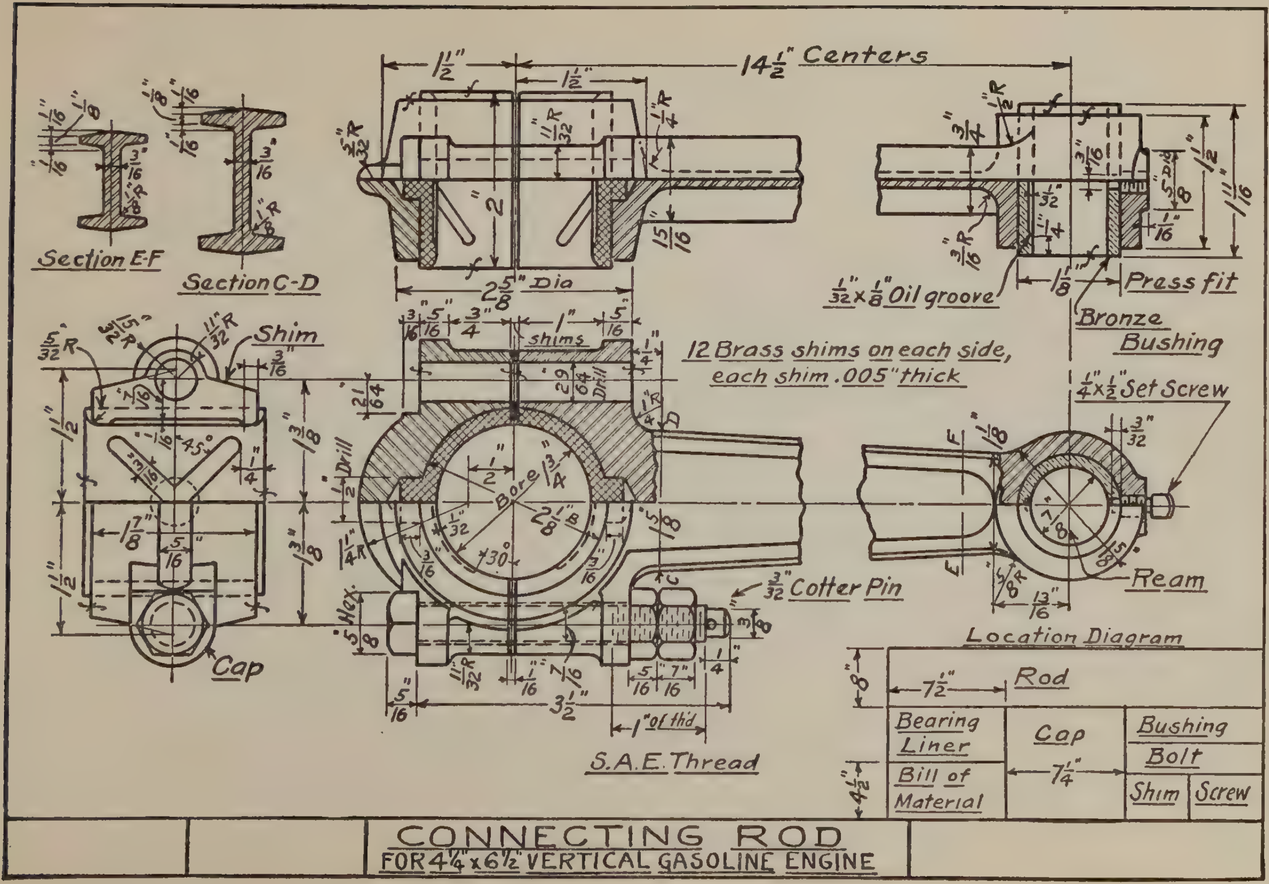
SPECIFICATION—PROBLEM 27

On the large size sheet make a complete detail drawing, including a bill of material, of the Connecting Rod shown on the lay-out sheet, page 113. Scale, 12 inches equals 1 foot. Each part is to be drawn and dimensioned separately and may be located in the spaces as suggested in the diagram. Views of a part should be kept near each other and away from views of another part.

The *Rod,* which is the largest part, is drop-forged of steel. Draw three complete views (without a break) and two isolated sections. The *Cap,* which is also drop-forged of steel, is the part which is bolted to the rod. Draw three views showing the top view in section. The *Bearing Liner* consists of two halves both alike, which are cast in a die of S. A. E. babbitt metal. Two views of one of the halves should be drawn. The *Bushing* is made of bronze and requires two views. The *Shim* requires one view with a note indicating the thickness. The *Bolt* may be drawn with the nut and lock nut in place and requires two views as does also the dog-pointed *Set-Screw.* The bill of material should include two cotter pins. Dimension each part separately and completely. Do not omit a dimension in one part because a similar dimension is given in another part.

This connecting rod is typical of those used in stationary and automobile gasoline engines. The small end is connected to the piston by means of a piston pin (see Problem 26) and the large end is fitted to the crank pin of the crank shaft (see Problem 24). It is a type of lever and assists in converting the reciprocating motion of the piston into the rotary motion of the crank shaft. The babbitt and bronze bearing liners have shallow oil grooves in them to assist in distributing the oil over their entire surfaces. The set-screw is to keep the bearing in place.

The connecting rod problem was taken from drawings contributed by the Worthington Pump Co., Gas Engine Division, Cudahy, Wisconsin.


14½" Centers
Section E-F
Section C-D
2⅝" Dia
Shim
12 Brass shims on each side, each shim .005" thick
shims
29/64 Drill
Bore 1¾"
2⅛"
30°
1/2 Drill
5/8 Hex.
Cap
3/32" Cotter Pin
1" of thd
S.A.E. Thread
1/32" x 1/8" Oil groove
Press fit
Bronze Bushing
1/4" x 1/2" Set Screw
Ream
Location Diagram
Rod
Bearing Liner
Cap
Bushing
Bolt
Bill of Material
Shim
Screw
7½"
7¼"
8"
4½"
CONNECTING ROD
FOR 4¼" x 6½" VERTICAL GASOLINE ENGINE

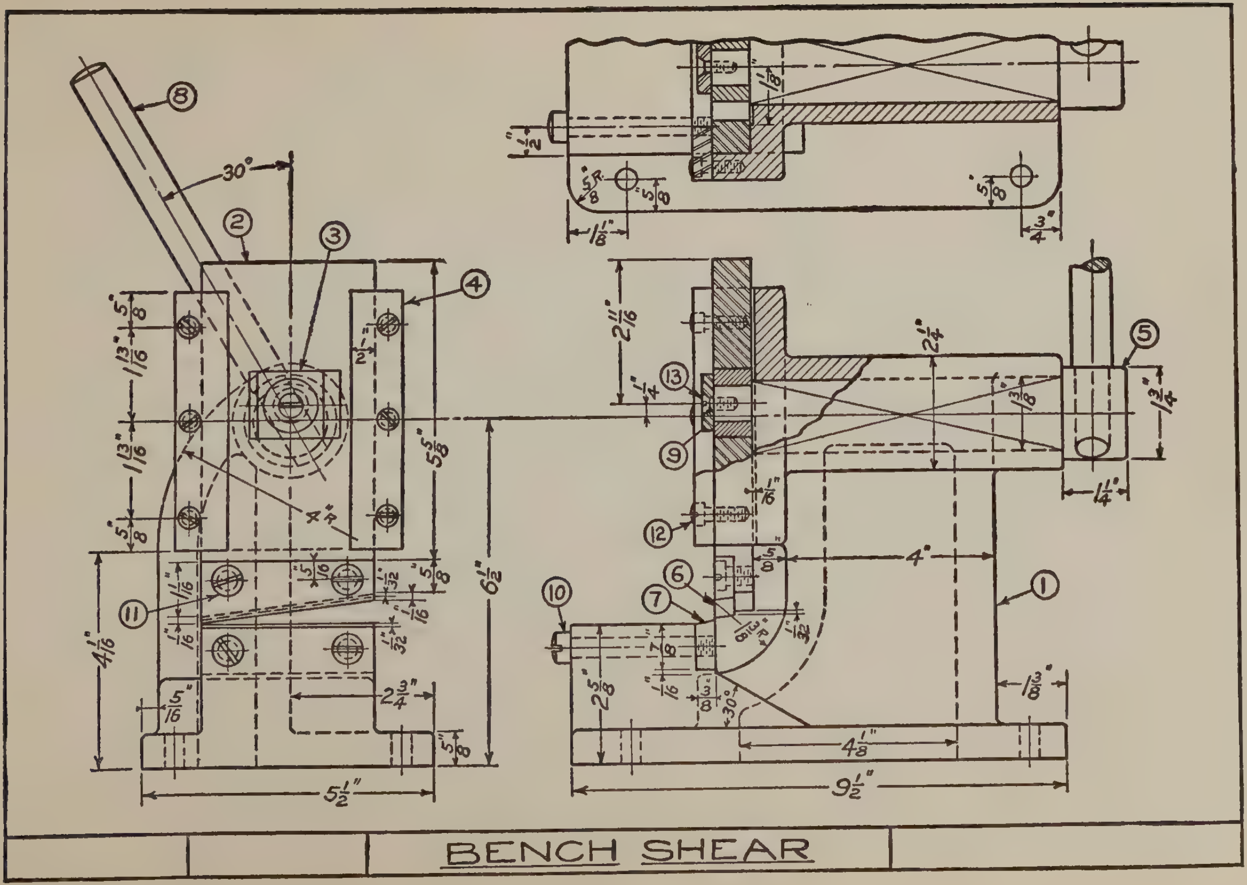
GROUP 4. SMALL MACHINES

SPECIFICATIONS FOR 3-INCH BENCH SHEAR—PROBLEM 28

Make a complete set of detail working drawings and an assembly drawing of the Bench Shear shown on the lay-out sheet, page 115. In the detail sheets, the drawing of each part is to be labeled with a sub-title giving the name of the part, and notes indicating the number required and the material it is to be made of. The views of a part should be near to each other but the drawings of the different parts well separated.

The Bench Shear is used for trimming sheet metal and cutting flat stock. The metal is cut between the *Lower Blade (7)* which is fixed to the Column *(1)* and the *Upper Blade (6)* which is attached to the movable *Ram (2)*. The ram is moved up and down by means of the *Shaft (5)* and the *Hand Lever (8)*. One end of the shaft is turned to a smaller diameter which is off-center or eccentric. On this end of the shaft is mounted the small cast-iron *Block (3)* which engages in a rectangular hole cut into the ram. When the shaft is rotated with the hand lever it imparts a crank line motion to the eccentric end which, thru the action of the block, moves the ram.

Drawing No. 1. Title: DETAIL SHEET 1 FOR 3-INCH BENCH SHEAR. Scale, 12 inches equals 1 foot. This sheet should include complete detail drawings of the following parts: *Shaft (5), Block (3), Washer (9), Handle (8).* The shaft is turned of machine steel and is finished all over. The small eccentric end is $\frac{11}{16}$ inch in diameter and is offset ¼ inch. This end of the shaft is drilled and tapped to receive a 14-20x¾ inch flat head machine screw which holds the block in place. The large end of the shaft is drilled to receive the handle. The block is made of cast-iron and is finished all over, the hole being reamed. It is ¾ inch thick and 1¼ inch square. The washer is ¼ inch thick by 1 inch diameter and is turned from the machine steel. It is drilled and


①
②
③
④
⑤
⑥
⑦
⑧
⑨
⑩
⑪
⑫
⑬
30°
5/8"
1 13/16"
1 13/16"
5/8"
4" R
5 5/8"
6 1/2"
4 1/16"
5/16"
1/16"
1/32"
1/16"
1/32"
5/16"
2 3/4"
5/8"
5 1/2"
1/2"
5/8 R.
5/8"
1 1/8"
1/8"
5/8"
3/4"
2 11/16"
1/4"
2 1/4"
1 3/8"
1 3/4"
1 1/4"
1/16"
5/8"
4"
7/8"
1/16"
3/8"
30°
2 5/8"
3/8 R.
1/32"
1 3/8"
4 1/8"
9 1/2"
BENCH SHEAR

countersunk to receive the 14-20 machine screw. The handle is made of ¾ inch cold-rolled steel, one end of which is turned to 11/16 inch diameter and 1 13/16 inch long. The length over all of the handle is 8¾ inches.

Drawing No. 2. Title: DETAIL SHEET 2 FOR 3-INCH BENCH SHEAR. Scale, 12 inches equals 1 foot. This sheet should include complete detail drawings of the following parts: *Ram (2), Guide (4), Upper Blade (6), Lower Blade (7), Upper Blade Screw (11).* The ram, which is ¾ inch thick and 3¼ inches wide, is made of machine steel and finished all over. One end is machined to hold the upper blade which is secured with two cap screws. The tapped holes should be labeled with the size of the tap drill as well as the size of the tap. The rectangular hole for the slide block is machined so as to allow 1/32 inch space between the hole and one side of the block when the ram is in its highest position and 1/32 inch space between the hole and the other side of the block when the ram is midway between its highest and lowest positions. The upper blade is made of 1 per cent carbon steel, is ⅜ inch thick, 1⅛ inch wide at one end, 11/16 inch wide at the other end, and is ground on the cutting edge so as to have a 1/32 inch bevel which is known as "clearance." The holes for the cap-screws are drilled and counterbored and must be fully labeled and dimensioned. The blade is "hardened and tempered," and has "all surfaces ground." Indicate this with notes. The lower blade is made of 1 per cent carbon steel. It is ⅜ inch thick and is held in place by two 24-16x2¾-inch fillister-head machine screws. The blade is hardened and tempered and has all surfaces ground, which should be indicated with notes. The Guides are made of ⅜ inch by 1 inch cold-rolled steel machined to length. They are held in place with 14-20x¾-inch fillister-head machine screws sunk in as indicated. The holes for the machine screws are drilled and counterbored. The upper blade-screw is similar to a regular round head cap-screw but has a lower head. The specifications are ⅜ inch diameter, 16 threads, 9/16 inch long. The head is 9/16 inch diameter, 3/16 inch high with a slot 1/16 inch wide and 3/32 inch deep.

Drawing No. 3. Title: DETAIL SHEET 3 FOR 3-INCH BENCH SHEAR. Scale, 6 inches equals 1 foot. This sheet is to include views of the *Column (1)* only. The column is cast of iron. The upright part is cored out such that the walls are ¾ inch thick. This part is offset on the base so that long lengths of band steel, etc., may be cut in the shear. The holes in the base are ⅜ inch diameter. Some provision should be made at the top of the column for oiling the shaft. The lay-out sheet does not show this.

Drawing No. 4. Title: 3-INCH BENCH SHEAR ASSEMBLY. Scale, 12 inches equals 1 foot. This drawing is to be made on the large-size sheet and should include three views as arranged on the lay-out sheet, showing all of the top view. Omit all dimensions except the total height without the handle, the total width, and the total length. A bill of material may be placed in the upper left hand corner if the handle is shown with a break. If this is done, all the parts should be labeled with the part numbers as indicated.

*SPECIFICATIONS FOR TRAHERN No. 00 ROTARY OIL PUMP—PROBLEM 29

Make a complete set of detail working drawings and an assembly drawing of the Rotary Oil Pump shown on the lay-out sheet, page 119. In the detail sheets the drawing of each part is to be labeled with a sub-title giving the name of each part, and notes indicating the number required, the material it is to be made of, etc. Do not hesitate to use explanatory notes, to make the drawing more clear, or to indicate methods of finishing, etc., and be sure to give all dimensions and information necessary to make each part. In using a note for specifying two or more holes that are to be alike, be sure to state the number of holes. The detail drawings may be given a filing number as *D-269-1, D-269-2,* etc., which should be placed at the right end of the record strip. The assembly drawing should in this case be numbered *A-269.*

Trahern Rotary Geared Pump.—This type of pump is very efficient when conveying oil and is adapted for supplying fuel oil to furnaces, etc. The principal mechanism is a pair of cut gears which rotate with the teeth in mesh in an accurately machined and closely fitted case. The case has two openings threaded to receive ¾ inch pipe for intake and discharge. The motion of the gears produces a partial vacuum which causes liquid to rise in the intake pipe. It is then carried in the spaces between the teeth of the gears to the discharge opening. The pump may be rotated in either direction and hence the liquid may be taken in or discharged from either opening.

Drawing No. 1. Title: BED PLATE FOR NO. 00 OIL PUMP. Scale, 6 inches equals 1 foot. This sheet should include a complete detail drawing of the *Bed Plate (1)* only. The bed plate is cast of iron; material ¼ inch thick unless specified otherwise. The *Bracket (2)* is secured to the bed plate

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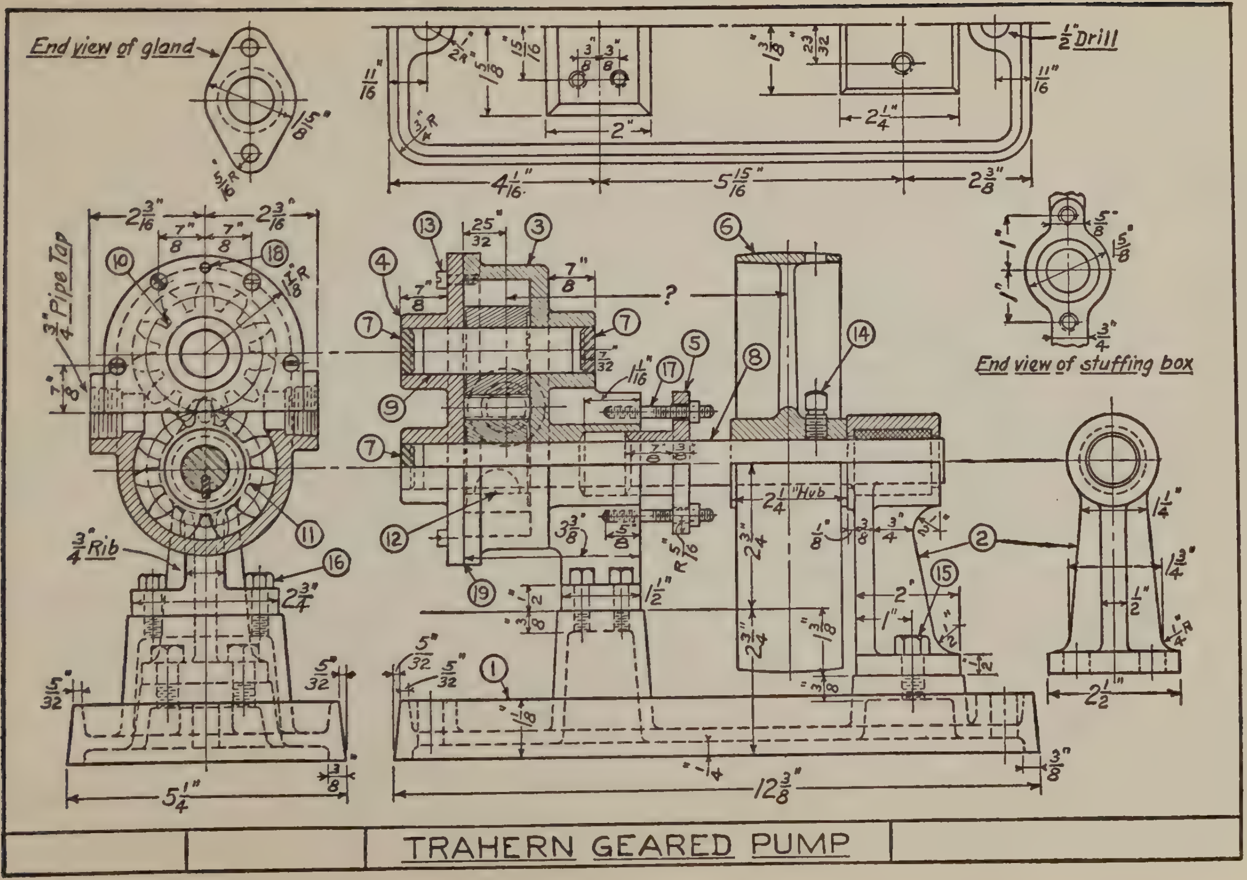
*Note: The geared pump problem was taken from drawings contributed by the Trahern Pump Division, Geo. D. Roper Corporation, Rockford, Ill.



TRAHERN GEARED PUMP

with two 7/16 inch by 1 inch hexagonal head cap-screws. The *Case (3)* is secured to the bed plate with four ⅜ inch by 1 inch hexagonal head cap-screws. The surfaces of the plate to which these parts are secured are machined and must be marked finished. Give size of tap drill in note for tapped holes as "⅝-inch Drill, ¾-inch Tap."

Drawing No. 2. Title: CASE AND SEAL PLUG FOR NO. 00 OIL PUMP. Scale, 12 inches equals 1 foot. This sheet should include complete detail drawings of the *Case (3)*, and the *Seal Plug (7)*. The case, which incloses the two gears *(10* and *11)*, is bored out very accurately with a special tool to a diameter which allows .002 inch clearance, between the tops of the teeth and the inside of the case and to a depth of .006 inch less than the face of the gears, which allows for a *Paper Gasket (19)* between the *Case* and the *Cover Plate (4)*. The shaft holes in the case and in the cover plate are reamed in a special jig to accurate center distances and ⅞ inch diameter. The dimension between the centers of these holes must be given in decimals to three places. The steel *Seal Plugs (7)* are pressed in flush with the ends of the hubs and are turned .003 inch larger than the shaft holes so as to make an airtight fit when in place. They are beveled 1/16 inch at 45 degrees on one face so as to help enter them when they are being pressed in place. The shaft hole in the case for the long shaft, is counterbored to form a stuffing box so as to allow 5/32 inch room around the shaft for packing. The packing is compressed, so as to prevent the pump from drawing air thru the bore around the shaft, with a *Gland (5)* and two 5/16 inch by 2 inch studs with hexagonal nuts *(17)*. The case is cast iron; material 5/16 inch thick unless otherwise specified. The cover plate is secured to it with eight 14-20x½ inch Fillister Head Machine Screws *(13)* on a 1⅝ inch radius circle. The surfaces secured to the *Cover Plate* and to the *Bed Plate* are machined. The intake and discharge openings are drilled thru with the tap drill for a ¾ inch pipe tap and then tapped to proper depth.

The cylindrical projections or "bosses" for these openings are 1½ inch in diameter. Give the size of tap drill in the notes for tapped holes.

Drawing No. 3. Title: COVER PLATE AND DOWEL PIN FOR NO. 00 OIL PUMP. Scale, 12 inches equals 1 foot. This sheet should include complete detail drawings of the *Cover Plate (4)* and the *Dowel Pin (18)*. The cover plate is cast-iron; material $\frac{5}{16}$ inch thick. The holes for the machine screws are counterbored $\frac{1}{16}$ inch deep, and a diameter slightly larger than the diameter of the head of the screw. The surface meeting the case is machined. The holes for the $\frac{3}{16}$ inch by $\frac{9}{16}$ inch steel *Dowel Pins (18)* are drilled after the pump is assembled and the pins are then driven in so that when the cover plate is removed it may be returned to its exact original position. Show centers only for holes and label with note: "Drill for dowel pins when pump is assembled." One end of the dowel pin should be rounded so that it enters easily.

Drawing No. 4. Title: SHAFTS AND GLAND FOR NO. 00 OIL PUMP. Scale, 12 inches equals 1 foot. This sheet should include complete detail drawings of the *Short Shaft (9), the Long Shaft (8),* and the *Gland (5)*. The shafts are of ⅞ inch cold-rolled round steel. The short shaft *(9)* is 2⅞ inches long; the long shaft *(8)* is 10⅛ inches long. Select the proper size of Woodruff key *(12)* for a ⅞ inch diameter shaft and draw key seat for same in the proper place on the long shaft to engage with the *Gear (11)*. The gland is cast of iron, bored and reamed to fit the shaft, and turned to fit into the stuffing box. The flange is left unfinished. The holes in the flange for the *Stud (17)* are drilled $\frac{1}{32}$ inch larger than the diameter of the studs.

Drawing No. 5. Title: BRACKET FOR NO. 00 OIL PUMP. Scale, 12 inches equals 1 foot. This sheet includes a detail drawing of the *Bracket (2)* only. The bracket is of cast-iron with a counter-cored hole into which the babbitt bearing metal is poured. Make the thickness of babbitt metal equal to .05 times the shaft diameter plus ⅛ inch; thickness of metal around babbitt equal to .35 times the shaft diameter. The surface which rests on the bed plate is machined. The holes for cap-screws are drilled. The drawing should show a ⅛ inch oil hole drilled thru the top of the bracket and countersunk slightly.

Drawing No. 6. Title: GEARS FOR NO. 00 OIL PUMP. Scale, 12 inches equals 1 foot. This sheet should include a complete detail drawing of the *Gear (11)* only. Gear No. 10 is exactly like No. 11 but has no key-seat, hence it is necessary to draw only the gear with the key-seat and affix the following note: "Two wanted, one without key seat." The gears are of cast-iron and are finished all over. One is pressed and keyed onto the long shaft and the other is pressed onto the short shaft. The hole is reamed with a special reamer, which is .873 inch diameter so as to make a tight press fit on the shafts. The data for the gear teeth is as follows: 11 Teeth, 5 Diametral Pitch, 14½ degrees involute. The gears are 1¼ inch face and are counterbored on both sides 1½ inch diameter by $\frac{1}{16}$ inch deep.

Drawing No. 7. Title: PULLEY FOR NO. 00 OIL PUMP. Scale, 12 inches equals 1 foot. This sheet should include a complete detail drawing of the *Pulley (6)* only. The pulley is 8 inches by 2 inches and is to be designed from table of pulley sizes on page 65. It is bored, turned, faced, and drilled and tapped for set-screws; set-screw size to be determined by formulae: The diameter of set-screw equals the shaft diameter divided by 8, plus $\frac{5}{16}$ inch. The tap-drill hole in the hub is drilled thru the rim with an extension drill.

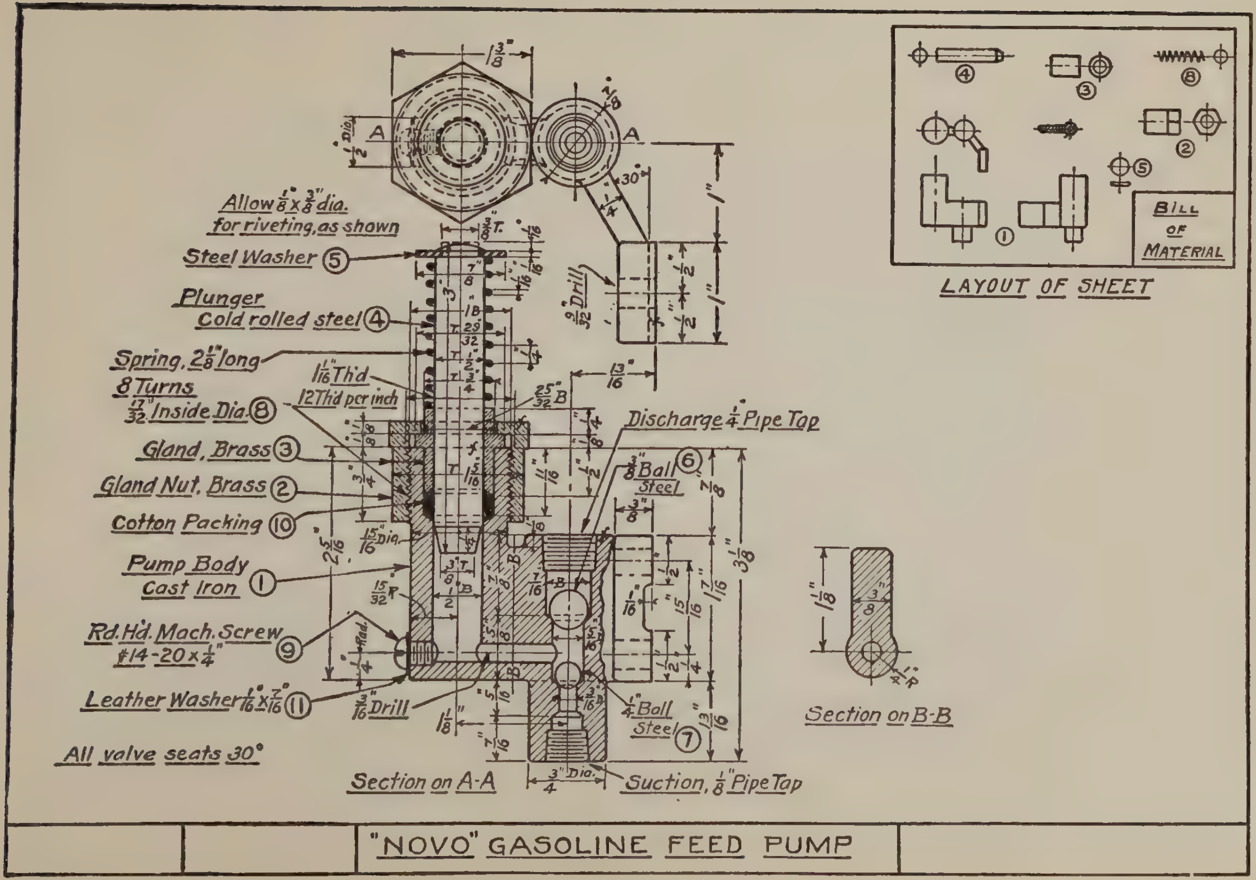
Drawing No. 8. Title: ASSEMBLY AND PARTS LIST FOR NO. 00 OIL PUMP. Scale, 12 inches equals 1 foot. This drawing is to be made on the large-size sheet and should include an assembly drawing of the pump consisting of two views on the upper part of the sheet and a parts list attached to the record strip. Omit the top view of the Bed Plate, the end view of the stuffing box and gland, and the end view of the bracket. Show the front view and the end view of the pump only. Draw these views as shown on the lay-out sheet with this exception: In the end view show the pulley, drawing only those parts of the pulley that are visible and omitting the parts that would be represented by dotted lines if they were drawn. Give following dimensions only: length of base; width of base; bottom of base to center of main shaft; bottom of base to center of pump outlet; center of outlet to center of pulley; total height of pump. Affix numbers in circles to all parts as indicated on the lay-out sheet.

The parts list or "Bill of Material" may be laid out in two "frames" or "boxes" adjacent to each other, each frame providing for ten parts. The spaces may be made ⅜ inch high and wide enough to suit the longest line in each column. The parts list should include, in the following order, the *reference number* of each part as given on assembly drawing; the number of *pieces required;* the *name of each part;* the *material* each part is made of, the *pattern number,* and the number of the *detail drawing if there is any.* Part No. 20, not shown in the assembly, should be included in the parts list as "Jewitt" Packing Rings ⅞ inch by $1\frac{3}{16}$ inch; four wanted.

SPECIFICATION FOR GASOLINE FEED PUMP—PROBLEM 30

From the assembly drawing shown on the lay-out sheet, page 125, make a complete detail working drawing of the "Novo" Gasoline Feed Pump. Scale, 12 inches equals 1 foot. The views of the parts which are to be drawn may be arranged as shown in the small "Lay-out of Sheet." Sectional views should be made use of wherever it is thought that they will make the drawing more clear. A bill of material which, may be placed in the lower right hand corner, should include the description and dimensions of parts not drawn.

This pump is used on the vertical gasoline engines of the Novo Gas Engine Co. and supplies the carburetor with gasoline from a tank in the base of the engine. It is a type of lift pump, the action of which can readily be understood by a study of the drawing. When the plunger is pushed down the gasoline in the pump raises the large steel bearing ball from its seat and passes through the discharge opening. When pressure is released the spring raises the plunger which tends to form a vacuum in the pump and hence raises the small bearing ball and draws gasoline thru the suction opening. The steel bearing balls, together with the seats that they rest upon, form the intake and discharge valves.


Allow 1/8" x 3/8" dia. for riveting, as shown
Steel Washer ⑤
Plunger Cold rolled steel ④
Spring, 2 1/8" long 8 Turns 17/32" Inside Dia. ⑧
1 1/16" Th'd 12 Th'd per inch
Gland, Brass ③
Gland Nut, Brass ②
Cotton Packing ⑩
Pump Body Cast Iron ①
Rd. Hd. Mach. Screw #14-20 x 1/4" ⑨
Leather Washer 1/16" x 7/16" ⑪
All valve seats 30°
Section on A-A
3/16" Drill
Discharge 1/4" Pipe Tap
3/8" Ball Steel ⑥
1/4" Ball Steel ⑦
Suction, 1/8" Pipe Tap
3/4" Dia.
9/32" Drill
Section on B-B
LAYOUT OF SHEET
BILL OF MATERIAL
A
A
B
B
30°
"NOVO" GASOLINE FEED PUMP

MISCELLANEOUS PROBLEMS

SPECIFICATION—PROBLEM 31

Make a working drawing of a Disk Crank as shown on the lay-out sheet, page 127. Select one of the sizes of engines given and determine the sizes of the crank from the table of proportions. This type of crank is used on steam engines and pumps.

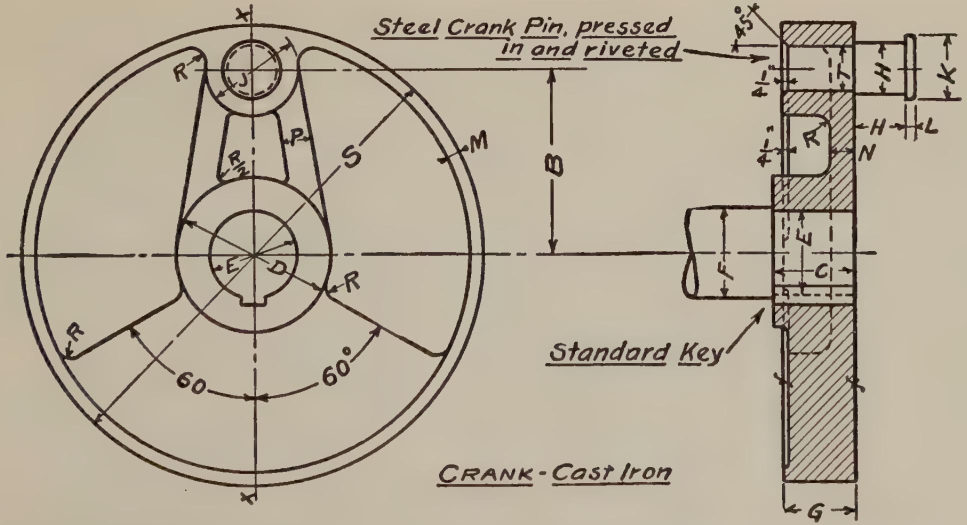
SPECIFICATION—PROBLEM 32

Make a working drawing of the Curved Arm Pulley as shown on the lay-out sheet, page 128. Show two complete arms, the other four in part only. Scale, 6 inches equals 1 foot. The drawing from which this problem was taken, was furnished by the Gray Planer Co. of Cincinnati, Ohio. The pulley is used on the main drive shaft of a Gray planer. Curved arms are used to overcome shrinking difficulties which were entailed in casting straight arm pulleys of this shape and material.

SPECIFICATION—PROBLEM 33

Make a complete working drawing of a Punch Press Fly-wheel as shown on the lay-out sheet, page 129. Select a diameter "A" from the table of proportions and use the scale noted for same.

A punch press is used in connection with punches and dies to cut and form sheet-metal parts. The fly-wheel is used as in other machines to store up energy which is released at certain intervals in its revolutions.


Steel Crank Pin, pressed in and riveted

Standard Key

CRANK - Cast Iron

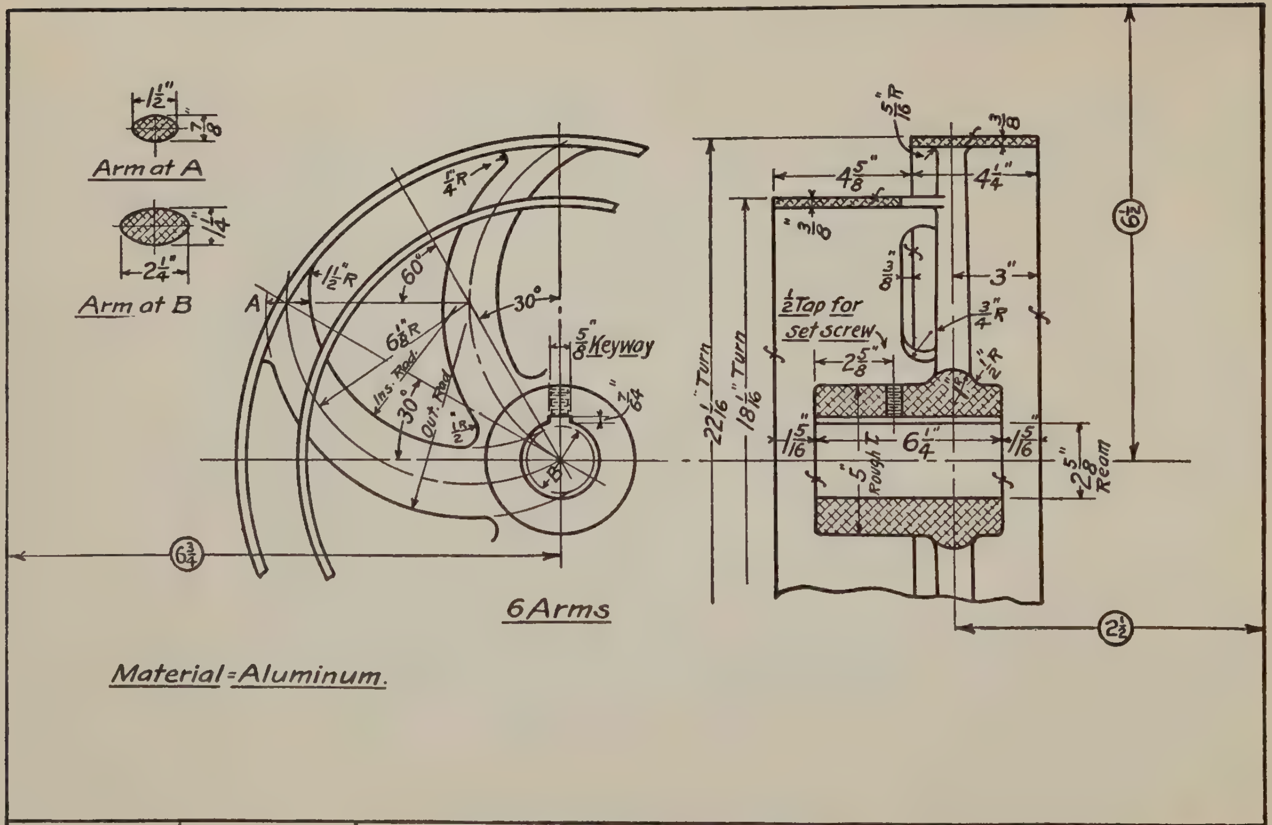
SIZES OF ENGINES.

Dia.	Stroke	Scale	Dia.	Stroke	Scale
13"	16"	3"=1'-0"	18"	42"	1½"=1'-0"
16"	36"	1½"=1'-0"	20"	36"	" "
16"	42"	" "	20"	42"	" "
18"	36"	" "			

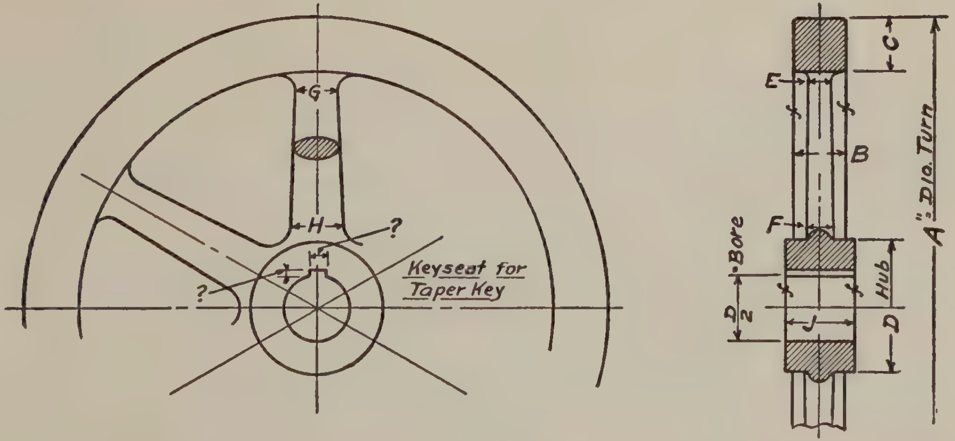
TABLE OF PROPORTIONS

A = Dia. of Cyl.	$F = .45A + \frac{1}{2}''$	$L = .08F$	$S = 2B + J$
B = .5 Stroke	$G = .75F$	$M = .163F$	$T = H - \frac{1}{8}''$
$C = .875F$	$H = .55F$	$N = .25F$	
$D = 1.75F$	$J = 1.125F$	$P = 2M$	
$E = F - \frac{1}{4}''$	$K = 1.3H$	$R = M$	

DISK CRANK



CURVED ARM PULLEY
FOR GRAY PLANER



REFERENCE TABLE OF PROPORTIONS

A	B	C	D	E	F	G	H	J	Scale	To be drawn
24	3	3½	6	1¼	1⅜	2¾	3¼	3½	6"=1'	⅔ Complete
30	3½	4	7	1⅜	1½	3	3¾	4	3"=1'	Complete
36	4	4½	8	1½	1¾	3¼	4¼	4½	3"=1'	⅔ Complete
42	4¼	4¾	9	1¾	2	3½	4½	5	3"=1'	⅔ Complete
48	4½	5	10	1¾	2	3¾	4¾	5½	3"=1'	⅔ Complete
54	4¾	5½	11	2	2¼	4	5	6	1½"=1'	Complete
60	5	6	12	2½	2½	4½	5½	6½	1½"=1	Complete
72	5½	7	13	2¾	2¾	5	6½	7	1½"=1	⅔ Complete

FLY WHEEL FOR PUNCH PRESS

SPECIFICATION—PROBLEM 34

Make a detail working drawing of the Bearing and Cap as shown on the lay-out sheet, page 131. Label each part with a sub-title and show all dimensions, notes, etc. Scale, 3 inches equals 1 foot.

The drawing from which this problem was taken was furnished by the Pawling & Harnischfeger Co. of Milwaukee, Wis., manufacturers of traveling cranes. This bearing supports the propeller shaft on an electric crane. The propeller shaft, which extends across the entire span of the crane, drives the crane along the runway. It is driven by a separate motor hung midway on the outside of one of the girders.

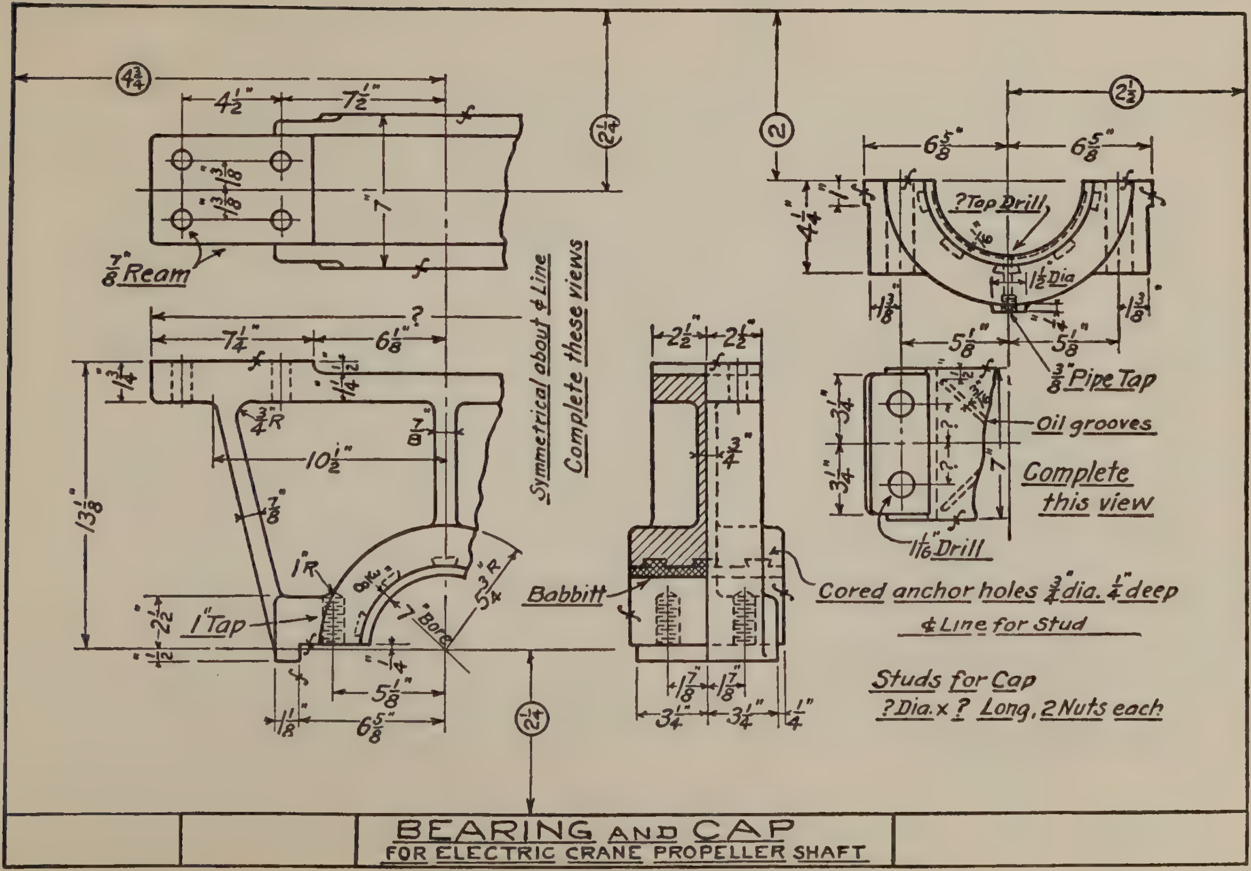
SPECIFICATION—PROBLEM 35

Make a detail working drawing of the Crank Shaft for Street Car Air Compressor as shown on the lay-out sheet, page 132. Draw one main view and a section of the crank, two views of the nut, two views of the washer and two views of the key. Scale for all drawings, 6 inches equals 1 foot. The cotter pin need not be drawn but must be specified in the bill of material. The drawing from which this problem was taken was furnished by the National Brake and Electric Co. of Milwaukee, Wis.

SPECIFICATION—PROBLEM 36

Make a complete working drawing of the Frame for ¼ H. P. D. C. Motor as shown on the lay-out sheet, page 133. The side view is to be shown in section; the front view and section on *A-A* are to be completed. Scale, 12 inches equals 1 foot.

The field coils, which are shown in outline, are held in place by ⅛ inch by 1½ inch steel pins which are driven in holes drilled in the pole pieces as shown. The outline of the field coils is sometimes shown on the drawing of the frame in order to design the heads or bearing brackets with necessary clearance for the coils.



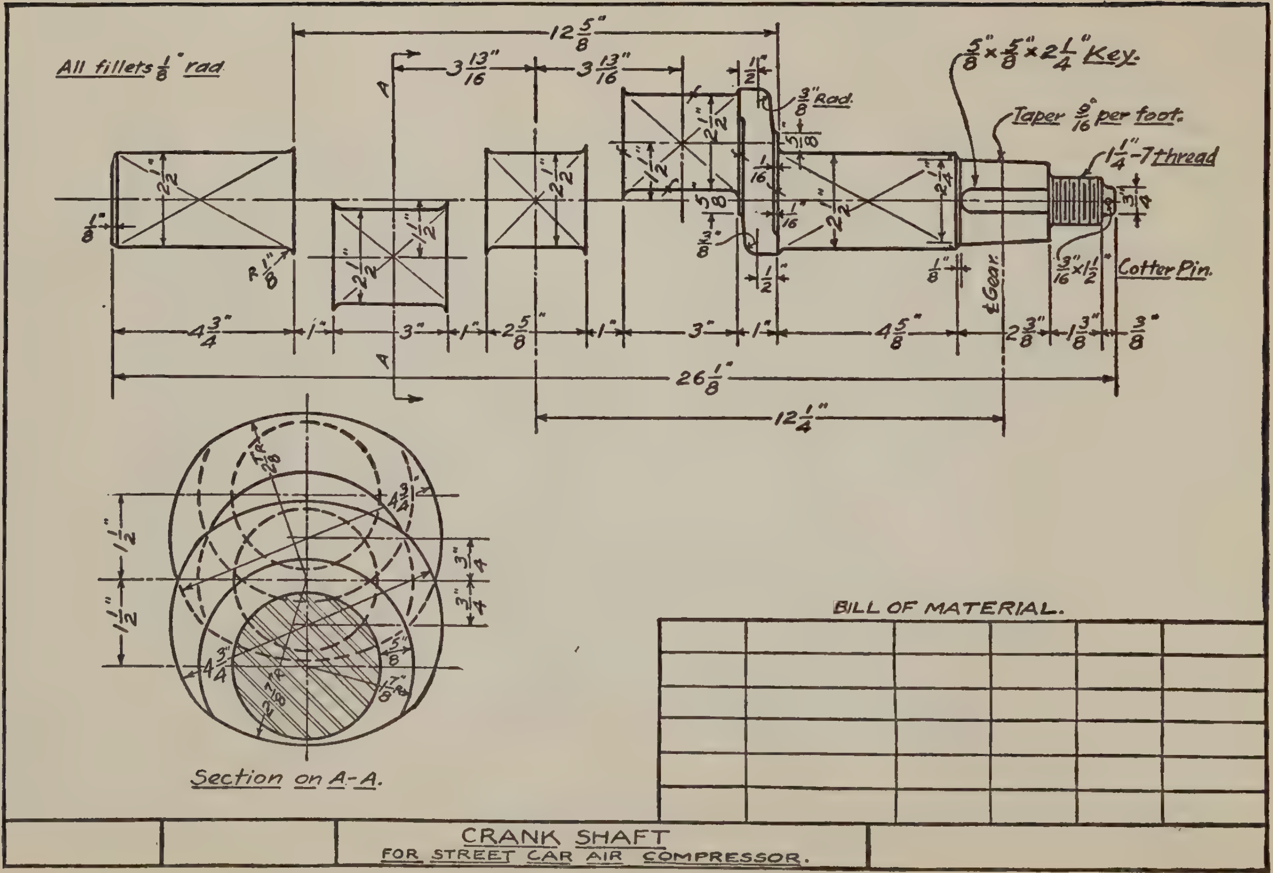
Symmetrical about ℄ Line

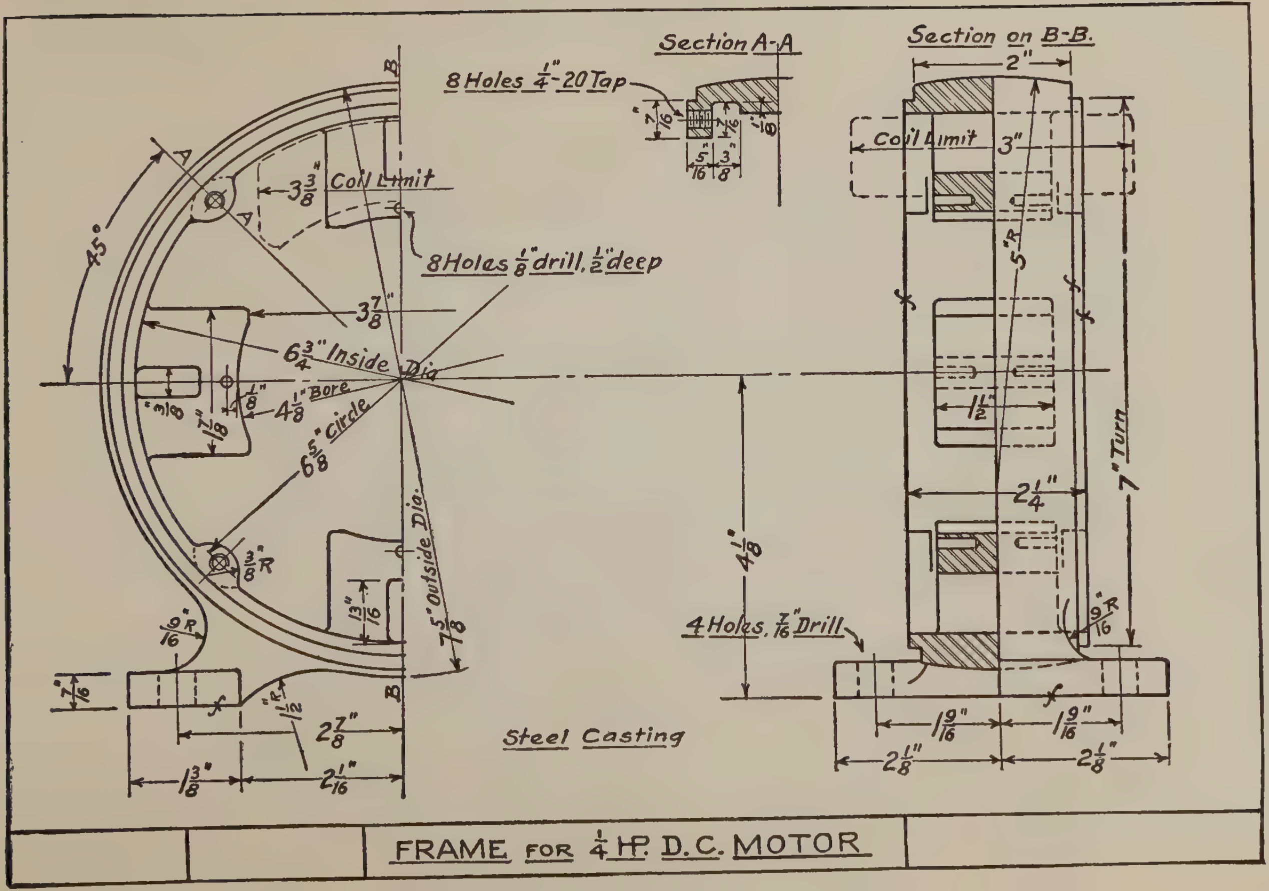
Complete these views

Complete this view

Studs for Cap
? Dia. x ? Long, 2 Nuts each

BEARING AND CAP
FOR ELECTRIC CRANE PROPELLER SHAFT


All fillets 1/8" rad.
12 5/8"
3 13/16"
3 13/16"
A
A
1/2"
3/8" Rad.
5/8" × 5/8" × 2 1/4" Key.
Taper 9/16" per foot.
1 1/4"-7 thread
3/4"
2 1/2"
1 1/2"
2 1/2"
1/8"
R 1/8"
1/16
5/8
3/8"
1/2"
2 1/4"
1/8"
℄ Gear.
3/16" × 1 1/2" Cotter Pin.
4 3/4"
1"
3"
1"
2 5/8"
1"
3"
1"
4 5/8"
2 3/8"
1 3/8"
3/8"
26 1/8"
12 1/4"
2 7/8 R
4 3/4
1 1/2"
1 1/2"
3/4"
3/4"
4 3/4
5/8"
1 7/8" R
2 7/8 R
Section on A-A.
BILL OF MATERIAL.
CRANK SHAFT
FOR STREET CAR AIR COMPRESSOR.


Section A-A
Section on B-B.
8 Holes 1/4"-20 Tap
7/16"
7/16
1/8"
5/16"
3/8"
2"
Coil Limit
3"
3 3/8"
Coil Limit
8 Holes 1/8" drill, 1/2" deep
45°
A
A
B
B
3 7/8"
6 3/4" Inside Dia
4 1/8" Bore
1/8"
3/8"
1 1/8"
6 5/8" Circle
5" R
1 1/2"
2 1/4"
7" Turn
3/8" R
1 3/16"
7 5/8" Outside Dia.
4 1/8"
9/16" R
9/16" R
7/16"
1/2" R
4 Holes, 7/16" Drill
f
2 7/8"
1 3/8"
2 1/16"
1 9/16"
1 9/16"
2 1/8"
2 1/8"
Steel Casting
FRAME FOR 1/4 H.P. D.C. MOTOR

SPECIFICATION—PROBLEM 37

Draw two complete views and a sectional detail of the Wire Rope Drum as shown on the lay-out sheet, page 135. The main views are to be drawn at a scale of 3 inches equals 1 foot. The detail of the grooves is to be drawn full size.

The drawing for this problem was furnished by the Pawling & Harnischfeger Manufacturing Co. of Milwaukee, Wis., and represents the hoisting drum for a 10-ton crane. The left end of the drum is turned to 16¾ inches diameter on which the driving gear is pressed and keyed. A shaft which is keyed and set-screwed to the drum extends thru the entire length of the drum and projects at the ends for bearings. An interesting problem is to determine the approximate lift of the drum.

SPECIFICATION—PROBLEM 38

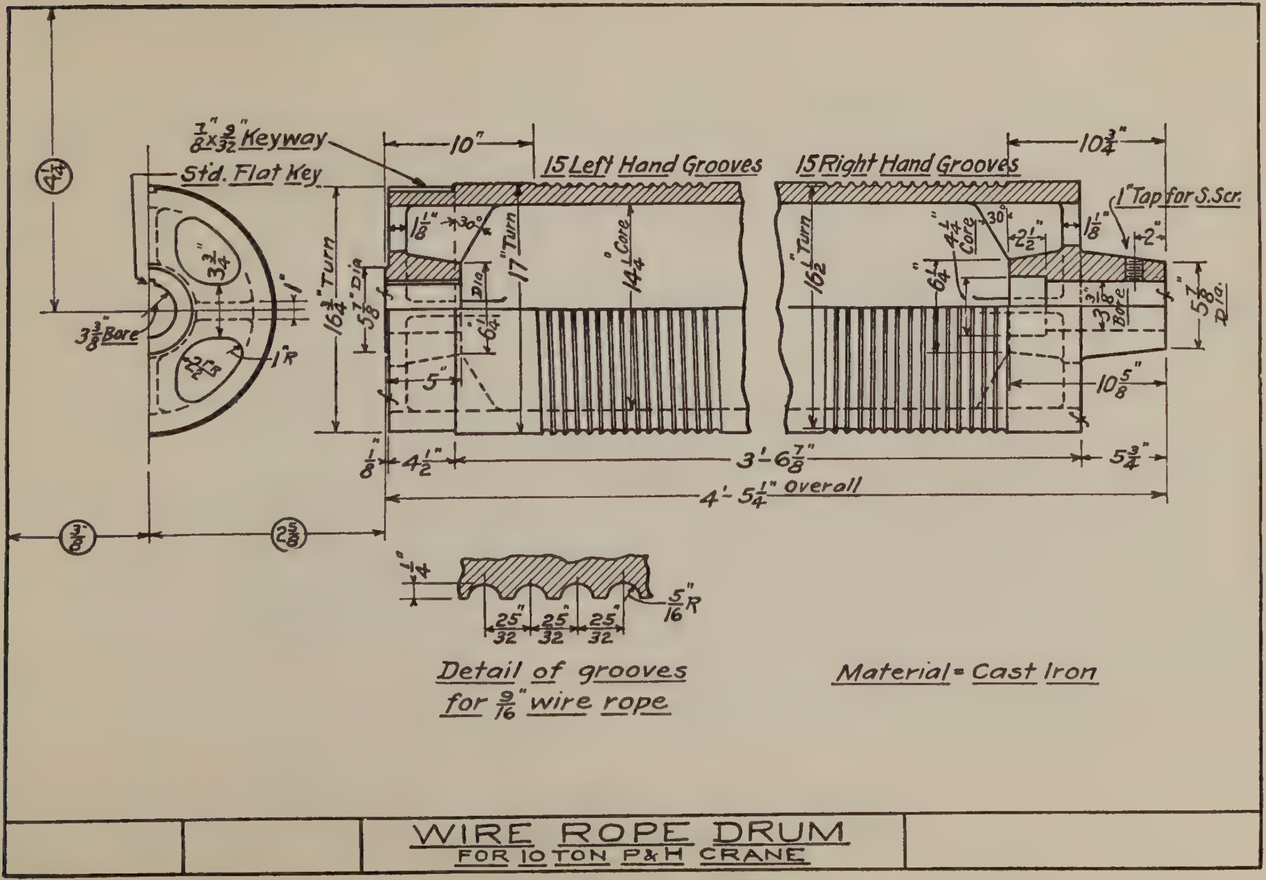
Draw the diagram of motion and two views of a Positive Action Cam as shown on the lay-out sheet, page 136. Scale, 12 inches equals 1 foot.

A roller or point follower must be held in contact with the surface of a cam by gravity, springs, or some other arrangement. With cams of certain shapes, the follower may be fitted with two rollers so placed as to afford a positive action without the use of a spring or gravity to hold the follower to the cam. In this case the following-bar is guided in an axial position by the shaft of the cam which engages a slot cut in the bar.

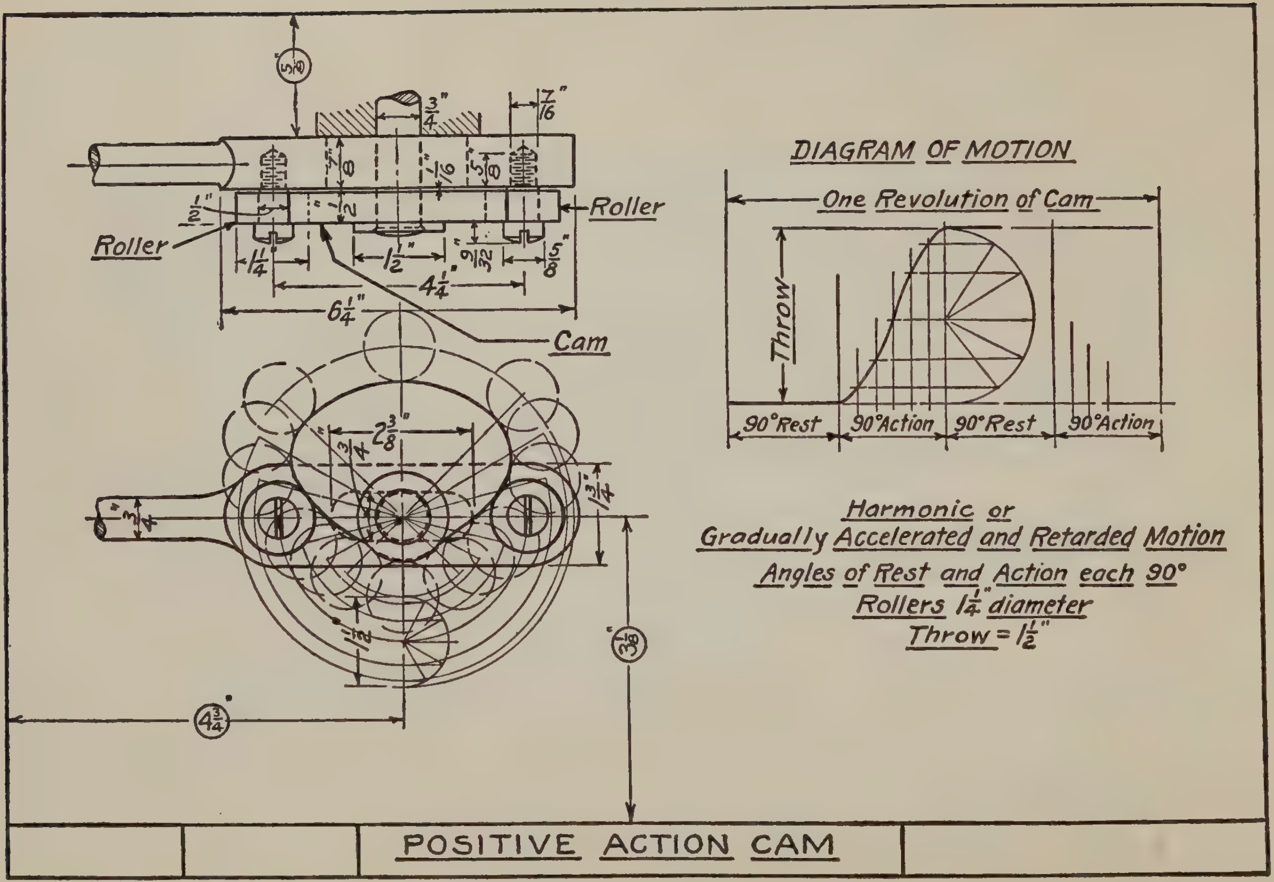
SPECIFICATION—PROBLEM 39

Make a drawing of a Wedge Socket for Steel Wire Rope as shown on the lay-out sheet, page 137, using one of the sizes given. The table of proportions is to be omitted and all actual sizes are to be given.

The wedge socket is a very effective method of securing ends of cables. The extreme end at *W* is secured with a regular cable clip.

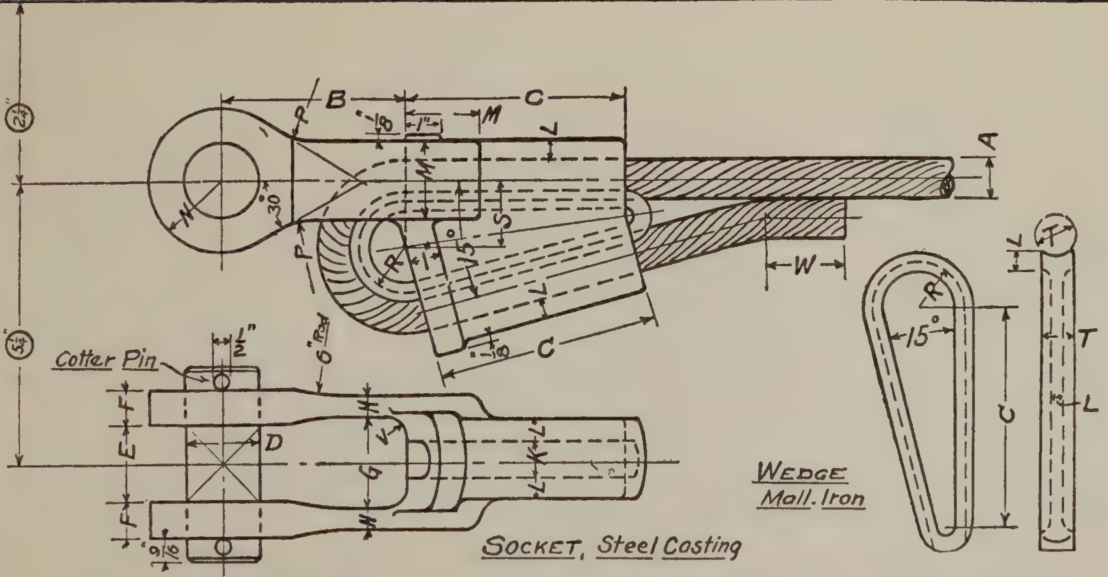


WIRE ROPE DRUM
FOR 10 TON P&H CRANE



Harmonic or
Gradually Accelerated and Retarded Motion
Angles of Rest and Action each 90°
Rollers 1 1/4" diameter
Throw = 1 1/2"

POSITIVE ACTION CAM



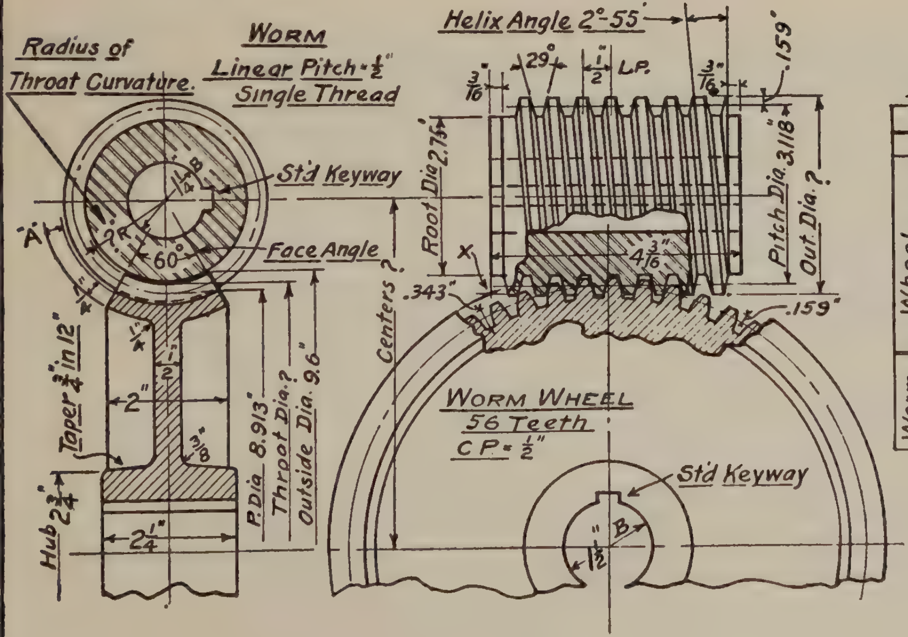
A	Dia. of Rope = 1", 1⅛" or 1¼"	F	A − ⅛"	M	2A + ⅛"	T	A + ⅛"
B	5A	G	2A	N	1.85A	V	.5A + 1/16"
C	6A	H	.5A + 1/16"	P	2A	W	about 2A
D	2A	K	A + 3/16"	R	1.5A − ¼"		
E	1.75A	L	.5A	S	2A − ¼"		

WEDGE SOCKET FOR STEEL WIRE ROPE

SPECIFICATION—PROBLEM 40

Make a drawing of the Worm and Worm-Wheel shown, or a drawing of a worm and worm-wheel, using data for one of the additional sizes given on the lay-out sheet, page 139. Scale, 12 inches equals 1 foot. The teeth of the worm-wheel are involute; those of the worm have straight sides inclined 14½ degrees. Calculations for the addendum, dedendum, clearance, tooth thickness, and pitch diameter are the same as for Browne & Sharpe spur gears. The throat diameter corresponds to the outside diameter of a spur gear. To find the radius of curvature of the throat of the worm-wheel, subtract twice the addendum of the worm tooth from half the outside diameter of the worm. To find the outside diameter of the worm wheel, multiply the radius of curvature of the throat by the cosine of half the face angle, subtract this quantity from the radius of curvature of throat, multiply the remainder by 2, and add the product to the throat diameter of the worm wheel. To find the helix angle of the worm (also known as the tooth angle), multiply the pitch diameter of the worm by 3.1416, and divide the product by the lead of the worm thread; the quotient is the cotangent of the helix angle of the worm. The helix angle is used in cutting teeth in the worm-wheel. The face angle is usually 60 degrees but may be made more or less to suit conditions. The length of the worm may be determined by projecting from the intersection of the outside lines of the worm and wheel as at point *X*.

Worm gearing is used to transmit power where a great reduction in velocity is desired, where a great increase in effective power is required or because of the smoothness of action. Worms for worm gearing are sometimes made with double or with other multiple threads. As the number of threads in the worm is increased the velocity ratio is decreased.



DATA FOR ADDITIONAL PROBLEMS

	Number of teeth	64	80
	Cir. Pitch	3/8"	1/4"
Wheel	Face Angle	60°	60°
	Pitch Dia. of Gear	7.369	6.366
	Outside Dia. "	7.913	6.801
	Addendum	.119	.079
	Clearance	.019	.012
	Dia. of Shaft	1¼"	1⅛"
	Length of Hub	2"	1⅞"
	Dimension "A"	3/16"	3/16"
Worm	Pitch Dia. Worm	2.375"	2.216"
	Thread Angle	29°	29°
	Helix Angle	2°-53'	2° 3'
	Dia. of Shaft	1"	1"

Single thread on worm in the 3 problems given.

WORM AND WORM GEAR

TEST QUESTIONS

The following questions are suggested for use in written examinations to test the student's knowledge and understanding of the things that are to be learned in the problems. It will be noticed that some of the questions are marked with an asterisk (*). Questions so marked are to be answered with the use of the book. All other questions must be answered without referring to the book. Other questions may be substituted or added, and graphic tests, in which the student expresses in a drawing the things learned, can be used effectively.

Bill of Material.

1. What information should be given in a bill of material?
2. When a bill of material is not given on a sheet which has drawings of several parts on it, what is necessary to complete the drawing?

Dimensioning.

3. Are dimensions important on a working drawing? Why?

Screw Threads.

4. Define a helix.
5. How can a screw with a left hand thread be distinguished from a screw with a right hand thread?
6. What is meant by a single thread; a double thread?
7. When are multiple threads used? Is the screw thread on a fountain pen cap single or multiple?
8. What is meant by the "pitch" of a screw? The "lead"?

Screw Thread Forms.

9. Name five screw-thread forms.
10. What form of thread is most commonly used on bolts?
11. Which of the screw-thread forms is the most desirable for transmitting motion as in moving the carriage of a lathe, and why?

Screw Thread Pitches.

12. Name three standards for screw-thread pitches and state the class of work for which each is used.

*13. Of what standard pitch is a bolt that is 1 inch in diameter and that has eight threads per inch? One-half inch diameter and twenty threads per inch?

Drawing of Screw Threads.

14. Why are screw threads not drawn as they actually appear?

15. How should the bottom of a threaded hole be drawn?

Standard Bolts and Screws.

16. Name the most common types of standard bolts and screws and state the form of thread and the standard screw-thread pitch on each type.

17. How are machine screw sizes designated?

18. For what purpose are studs used?

Bolts, Nuts, and Screws.

19. Give the proportion based on the diameter for U. S. S. machine bolt sizes as follows: distance across flats of square and hexagonal head and nut; height of head, and height of nut.

20. When a cap-screw is used as a fastening, what should be the proportionate length of the part that screws into cast-iron? Into steel?

*21. What size tap drill should be used for the threaded hole for the stud in problem No. 1? What size for the cap screw?

*22. A cast-iron machine part one inch thick is to be secured to a steel casting with a ¾-inch diameter cap-screw. The steel member is to be drilled and threaded to receive the cap-screw. What size hole should be drilled in the steel part and how deep should the hole be drilled? What is the length of the cap-screw necessary?

Screw Fastenings.

23. What is the purpose of set collars and how are they fastened to shafts?

24. What diameter of set-screw is appropriate to fasten a pulley to a shaft 2 inches in diameter? 2¾ inches in diameter?

25. A plain set collar is to be fastened to a shaft 1 inch in diameter with a socket set-screw. Determine the diameter and length of the set-screw, and the width and diameter of the collar.

*26. Determine the size of body drill and tap drill for the round-head machine screw of Problem No. 2.

*27. A cast-iron cover ⅜ inch thick is to be secured to a cast-iron pump case with six 10-32 flat head machine screws. Determine the length of screw necessary, the size of body drill and tap drill and the total depth of the tapped hole.

Lock Nut.

28. Describe two methods that are used to prevent a nut from unscrewing.

Piping.

29. Which diameter corresponds more nearly to the nominal size of standard pipe, the inside or the outside?

30. What is meant by "extra strong" pipe?

31. Why are pipe threads cut on a taper?

*32. What should be the size of the tap drill and the depth of the thread, of a hole which is tapped to receive a ¼ inch pipe? A ⅜ inch pipe? A 1 inch pipe?

*33. Two pieces of ¾ inch pipe which are in a vertical position and parallel to each other are to be connected at their ends with a horizontal piece of pipe by means of two elbows. The vertical pipes are 14 inches apart, center to center. Determine the length of the horizontal piece of pipe.

Keys

34. What is the principal function of keys?

35. What types of keys are most commonly used in machine construction? What is the average practice in proportioning them?

36. Name and describe a form of key which is patented.

37. Determine the diameter of the hub and the proper size key for the following: (a) A gear mounted on a shaft which is 7 inches in diameter; (b) A pulley mounted on a shaft which is 3 inches in diameter.

38. What is the purpose of a taper key and why is it sometimes made with a gib head?
39. What is a key-seat?
40. Explain the purpose and use of a feather-key.
41. What do light cross lines on the drawing of a shaft indicate?
42. A solid cast iron pulley mounted on the line shaft in a shop is to be subjected to a heavy load. What would you consider a good method of securing the pulley to the shaft?

Rivets and Riveted Joints.

43. Name the common types of rivet heads.
44. What is meant by the "point" of a rivet?
45. Explain the following: Chain riveting; staggered riveting; lap.
46. How is a lap joint constructed? A butt joint?
47. What is meant by calking?

Structural Drawing.

48. Name two common structural steel forms and show by example how the sizes should be specified.
49. What is meant by "shop rivets"? By "field rivets"?
50. What is the purpose of the Osborne rivet code?

Storage Tank.

51. What is a manhole and what is its purpose?
52. Show by a sketch how the ends of small tanks are placed.

Flange Coupling.

53. What is a coupling and what is it used for?
54. Should U. S. S. machine bolts be used in bolting together a flange coupling? Why?

Universal Coupling.

55. Describe the construction and explain the operation of a universal coupling. A free hand sketch may be used to illustrate.

Slip Coupling.

56. What is the purpose of a slip coupling?
57. Explain the operation of a slip coupling. Use a sketch if necessary.

Shafting and Pulleys.

58. Name two kinds of shafting and tell all you can about them.
59. Of what materials are pulleys for belt drives generally made?
60. What is meant by "crowning" on a pulley and what is its purpose?

Pulleys for Countershafts.

61. What is the purpose of a countershaft?
62. Why are the tight and loose pulleys on a countershaft made without crowning?

Bearings.

63. Name three types of bearings.
64. What is the purpose of bearing metals?
65. State the composition of S. A. E. babbitt metal.
66. What important provisions should be made in designing a good bearing?
67. Why are oil holes in bearings often threaded with pipe threads?
68. A cast-iron box for 2-inch shaft is to be lined with babbitt metal. What should be the thickness of the babbitt metal ("P" in table) and the thickness of the cast iron around the babbitt ("W" in table)?
69. What is the purpose of "shims" in a bearing?

Spur Gears.

70. What is a spur gear?
71. Define the following terms as related to spur gears: Pitch circle, pitch diameter, addendum, dedendum, clearance, outside diameter, diametral pitch, circular pitch.
72. Name the form of tooth curve most commonly used in spur gears.
73. Name the two most common systems of tooth proportions for spur gears and state the essential differences between them.

74. Calculate the pitch diameter, outside diameter, total depth of tooth, diameter of base circle, and thickness of tooth for (1) a Browne & Sharpe gear of 48 teeth, 8 diametral pitch with cut teeth;
    (2) a cast tooth gear of 36 teeth, 2 diametral pitch;
    (3) A Fellow's stub tooth gear of 60 teeth, 6/8 pitch, with cut teeth.
75. (a) Why is it unnecessary in most cases to draw the gear tooth outlines on drawings for spur gears with cut teeth?
    (b) When is it necessary?
    (c) Give the name of, and explain a method of drawing approximate gear tooth outlines.
76. What information and dimensions are very important on a drawing of two spur gears in mesh?
77. (a) What is a "pinion"?
    (b) For what purpose is a "rack" used?
78. What shape of gear arm is very generally used? Why?

Bevel Gears.

79. For what purpose are bevel gears used?
80. What is meant by the "pitch cones" in a pair of bevel gears?

Cams.

81. What is a cam?
82. Name two types of cams and describe the motion each imparts to a follower.
83. What type of cam may be used to guide a thread which is being wound on a bobbin or spool?

Gasoline Engine Parts.

84. What is the purpose of a crank-shaft in a gasoline engine?
85. What is the purpose of a fly-wheel in a gasoline engine?
86. What is the purpose of a counterweight in a fly-wheel?
87. Explain the action of a piston in a gasoline engine.
88. What is the purpose of piston rings?
89. Why are piston rings often made eccentric?
90. Explain the purpose of a connecting-rod in a gasoline engine.

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